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(54) Title: METHOD AND APPARATUS FOR MAKING ELECTRICAL TRACES, CIRCUITS AND DEVICES

(57) Abstract

A printer forms conductive traces on the print media for circuit connection, such as for connecting to integrated circuit chips. The printer prints the conductive traces according to a digital representation of a desired conductor pattern produced with a computer system, thus eliminating typical masking and photolithographic steps. In one embodiment, the printer includes three print heads in series and a transport mechanism that transport the print media past the print heads to print conductive, dielectric, and/or ferromagnetic inks. In another embodiment, the printer includes a single print head that sequentially prints each of the inks. By printing not only conductive material, the printer can print various impedance elements, including resistors, capacitors, and inductors. The printer can also print N- and P-type material to produce active circuit elements. The printer can print various other electrical devices, all in a very inexpensive manner.

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METHOD AND APPARATUS FOR MAKING ELECTRICAL TRACES, CIRCUITS AND DEVICES

TECHNICAL FIELD

The present invention relates to manufacturing conductive traces and electrical circuits.

BACKGROUND OF THE INVENTION

Many electrical circuits are fabricated today as integrated circuits using semiconductor fabrication techniques. The integrated circuits, or "semiconductor chips," are typically fabricated by depositing two or more layers of metallic, insulating or semiconductor material on a semiconductor substrate. The deposited material is laid out in a predetermined pattern so that the spatial layout or "topology" of the layers of material perform electronic circuitry functions.

A "mask work" is a series of related images or masks of the predetermined three-dimensional pattern of material present or removed from the layers of a semiconductor chip. Each mask represents a layout of material deposited on, or removed from, the chip during one step of a multi-step process required to manufacture the chip. For example, material is deposited on or removed from the semiconductor substrate using vapor, chemical and metal sputtering deposition, chemical and mechanical planarization and other techniques to position circuitry monolithically on the semiconductor substrate. Such semiconductor fabrication techniques have realized tremendous circuit density, as well as complex and reliable circuit elements.

Semiconductor manufacturing techniques, however, require costly machines for making such circuits. Therefore, the price of circuitry increases, and barriers to entry exist for individuals who wish to manufacture semiconductor circuitry. Additionally, designing semiconductor circuits requires highly trained engineers. Such engineers employ computer-aided design and other computerized techniques for manufacturing semiconductor circuits. The computer-aided design techniques help the engineers to develop mask works for the semiconductor circuits. Such circuit design

takes time, and is therefore costly. Overall, someone who wishes to produce only a small number of semiconductor circuits must pay high prices for the design and manufacture of such circuitry.

Some electrical traces can be formed with less cost than semiconductor circuits. Printed circuit boards are typically formed as a pattern mask for each layer of interconnections or traces. A given layer is defined by the pattern mask and photochemically etched through solid layers of conductors over substrates, for instance, copper over FR4. Still, such circuit board manufacturing techniques are costly, and require substantial time and expense to design one board.

Coupling circuits to a board can similarly be costly and/or time consuming. Circuit elements can be placed on a previously fabricated printed circuit board using pick and place machinery. A conductive material, such as an electrically conductive, ultraviolet-curable, heat-fusible adhesive can be applied to terminals of electrical components to couple such terminals to the printed circuit board. An ultra-violet light source is in use to fuse or cure the adhesive to affix and electrically couple the components to the print circuit board. Other methods of electrically and mechanically coupling components to a printed circuit board or other substrate include using electron beams, ultrasonic waves, or a two-part curing process. All of such methods are at least costly, and tend to be time consuming.

SUMMARY OF THE INVENTION

In a broad sense, the present invention embodies a system for printing electrical circuits that includes a computer and a printer. The computer has a memory, an input device, and a display screen. The memory contains program instructions for the computer to (a) receive instructions input by a user through the input device to create an electrical circuit, (b) display on the display device a graphical representation of the user created electrical circuit, and (c) provide print instructions that represent the user created electrical circuit. The printer is coupled to receive the print instructions from the computer and includes a print engine for printing the electrical circuit on a

print media using at least one ink having a predetermined electrical characteristic. Examples include conductive ink, resistive ink, N- and P-doped inks, and magnetic ink.

Another embodiment of the invention is directed to a method of printing on a print media that includes the steps of (a) defining a pattern of conductors, and (b) printing a conductive trace on the print media in the defined pattern by applying a conductive ink with a print head. An embodiment of the invention also includes an article of manufacture for a printer that includes a print media of a flexible or stiff, planar and electrically insulative material. The print media is capable of having conductive traces printed thereon. The print media has formed therein a plurality of spaced apart conductive members, wherein a pair of holes in the print media expose two portions of each conductive member.

Another embodiment of the invention is directed to a printer that includes a print engine and a print controller. The print engine is operative to print a conductive material in a pattern defined by a first electrical signal. The print controller is coupled to the print engine and is operative to receive data representing an electrical circuit to be printed, and to provide the first electrical signal in response to the received data.

Another embodiment of the invention is directed to a method of creating circuit elements. The method includes (a) providing a print media; (b) defining a first pattern for conductive material; (c) defining a second pattern for insulative or resistive material; (d) printing conductive material on the print media in the first defined pattern by applying a conductive ink with a print engine; and (e) printing insulative or resistive material on the print media in the second defined pattern by applying an insulative or resistive ink with the print engine.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a partial block, partial front elevational view of a computer system having a display screen, which is coupled to a printer for printing electrical circuits under an exemplary embodiment of the invention.

Figure 1B is a flowchart diagram of a method for printing conductive traces and/or circuits under the system of Figure 1A.

Figure 2 is a top view of a substrate or print media that has embedded integrated circuits, on which the printer of Figure 1A prints conductive traces.

Figure 3 is a top plan view of an alternative print media having conductive traces printed by the printer of Figure 1A, to which an integrated circuit can be mounted.

Figure 4 is a side view of a first method for mounting integrated circuits to the print media of Figure 3.

Figure 5 is a side view of a second method for mounting integrated circuits to the print media of Figure 3.

Figure 6A is a side view of a third method for mounting integrated circuits to the print media of Figure 3.

Figure 6B is a side view of a fourth method for mounting integrated circuits to the print media of Figure 3.

Figure 7 is a top plan view of an identification card and key that can be printed by the printer of Figure 1A.

Figure 8A is a top view of a portion of print media having embedded conductors therein.

Figure 8B is a cross-sectional view taken along the line 8B-8B of Figure 8A.

Figures 9A is a top view of a portion of another print media having embedded conductors therein.

Figure 9B is a cross-sectional view taken along the line 9B-9B of Figure 9A.

Figure 10A is a top view of a portion of yet another print media having embedded conductors therein.

Figure 10B is a cross-sectional view taken along the line 10B-10B of Figure 10A.

Figure 11 is a diagrammatic representation of the printer of Figure 1A having three separate print heads and ribbons.

Figure 12 is an enlarged, cross-sectional view of an example of a ribbon for use with the printer of Figure 11.

Figure 13A is an enlarged, cross-sectional view of an example of another ribbon for use with the printer of Figure 11.

Figure 13B an enlarged, cross-sectional view of is an example of another ribbon for use with the printer of Figure 11.

Figure 14 is a diagrammatic representation of a printer having a three-part ribbon.

Figure 15 is a isometric view of another ribbon for use in an alternative embodiment to the printer of Figure 14.

Figure 16 is a side elevational view of yet another ribbon for use in an alternative embodiment to the printer of Figure 14.

Figure 17 is a top plan view of a tag according to one embodiment of the invention.

Figure 18 is a block diagram of an RF tag according to one embodiment of the invention including a printed symbol and a memory device.

Figure 19 is a top plan view of the tag of Figure 17 showing a first set of conductive traces printed with the printer of Figure 11.

Figure 20 is a top plan view of the tag of Figure 17 showing the first set of conductive traces and a dielectric layer printed with the printer of Figure 11.

Figure 21 is a top plan view of the tag of Figure 17 with a second set of conductive traces printed with the printer of Figure 11.

Figure 22 shows three types of resistive elements printed by the printer of Figure 11.

Figure 23 is an isometric view of two capacitors printed by the printer of Figure 11.

Figure 24 is a partial top plan view, partial block diagram of four impedance elements that can be printed and selectively coupled by the printer of Figure 11.

Figure 25 is a greatly enlarged cross-sectional view of a PNP transistor printed by the printer of Figure 11.

Figure 26 is an isometric view of a capacitive switch printed by the printer of Figure 11.

Figure 27 is a top plan view of a seven-segment electroluminescent display printed by the printer of Figure 11.

Figure 28 is a top plan view of an alternative print media having conductive pads formed on an upper surface thereof.

Figure 29A is a top view of a portion of yet another print media having conductors secured thereto.

Figure 29B is a cross-sectional view taken along the line 29B-29B of Figure 29A.

Figure 30 is a side elevational view of three layers of print media having conductive traces formed thereon.

Figure 31 is a schematic diagram of a thermal print head, ribbon, and print media, with corresponding transport rollers.

Figure 32 is a schematic diagram of another ribbon for use in the printer of Figure 14.

Figure 33 is a top plan view of print media having conductive traces and resistive elements printed by an alternative embodiment of a printer.

Figure 34 is an enlarged, cross-sectional view of an example of another ribbon for use with the printer of Figure 11.

Figure 35 is an enlarged, cross-sectional view of an example of another ribbon for use with the printer of Figure 11.

DETAILED DESCRIPTION OF THE INVENTION

A method and apparatus for making electrical circuits and devices is described in detail herein. In the following description, numerous specific details are provided such as methods of printing electrical circuits, materials, geometries, etc., to provide a thorough understanding of the present invention. One skilled in the relevant art, however, will readily recognize that the present invention can be practiced without one or more of the specific details, or with other printing methods, materials, geometries, etc. In other instances, well-known structures or operations are not shown in detail to avoid obscuring the present invention.

An exemplary embodiment of an overall system for printing conductive traces and circuits is first described below. Second, methods of electrically coupling integrated circuits (ICs) with printed conductive traces and a security card/key example are described. Third, methods of printing interconnections between conductive traces and vias in a printable substrate are described. Fourth, printers and ribbons for printing electrical circuits are described. Finally, printing of electrical circuits is described, with reference to an exemplary remotely readable tag.

Overall System

Referring to Figure 1A, a system 100 under an exemplary embodiment of the invention includes a computer 102 coupled to one or more input devices 104, a visual display device 106, and a printer 108. The input devices 104 can include a keyboard, mouse, scanner, pen and/or tablet, as well as machine-readable symbol input devices such as laser scanners, two-dimensional imagers, etc. Input devices for inputting data into a computer, as well as devices for automatically gathering data from machine-readable symbologies are well known in the art, and need not be described in further detail.

Referring to Figure 1B, the computer 102 performs a routine 115 for permitting a user to create conductive traces or electrical circuits that are printed by the printer 108. Beginning in step 117, the user assembles or draws conductive traces and/or circuit elements. Under step 117, the routine 115 employs a graphics-type

environment, whereby the user manipulates a mouse, keyboard or other input device 104 to draw or create, for example, conductive traces 112 that are displayed in a window 110 of a graphical user interface (GUI). The user in step 117 can draw a series of lines or geometric shapes on the screen which represent traces or circuit elements. The user in step 117 also identifies the material to be printed by the printer 108 (*e.g.*, conductive material, insulative material, etc.). The user may need to design two or more layers to generate a graphic representation of printable circuits, similar to a mask work.

Alternatively, the routine 115 in step 117 can employ a drag-and-drop interface that permits the user to drag various circuit elements (represented as icons) from a toolbox or menu into a drawing or work space in a window, and connect the elements (in a fashion similar to that with products produced by Visio Corporation, Seattle, Washington).

In yet another alternative embodiment, the routine 115 in step 117 can automatically assemble desired circuit elements and systems based on a data file previously generated by another software routine. The user can employ a computer generated design (CAD) program to draw desired electrical traces or circuitry and produce an output file (*e.g.*, an IGES or STEP file). For example, the CAD program can produce the topology or layout of a prototype printed circuit board, which is stored as an IGES file. The routine 115 in step 117 then employs an appropriate input filter or conversion program to convert the IGES file into a bitmap, vector or other file or data structure that the printer 108 employs to print the prototype board.

After the user has created the desired circuit traces (and possibly tested such traces automatically using the computer 102), the user instructs the computer to store and/or forward the completed design to the printer 108 in step 118. In step 119, the routine 115 causes the printer 108 to print, for example, conductive traces 116 on a print media 114. For example, assuming the printer 108 is a thermal printer, the computer 102 and/or the printer 108 converts the graphical image of one or more layers into a bitmap, vector, or other data file that the printer can use to print the desired conductive traces 112. The printer 108 under step 119 selectively energizes elements in

print heads to print the completed design with the previously identified print material. As a result, the conductive traces 112 displayed by the display device 106 are graphically depicted in a manner similar to the traces 116 printed by the printer 108.

Coupling Integrated Circuits To Printed Traces

Referring to Figure 2, one exemplary embodiment for electrically coupling ICs to conductive circuits or traces printed by the printer 108 employs previously manufactured ICs 120 embedded or affixed to the print media 114. (The terms "traces" and "circuits" are generally used interchangeably herein to refer to printing defined conductive portions on a print media.) As shown in Figure 2, the print media 114 includes ICs 120 regularly spaced longitudinally along and at a transversal mid-point of the print media. Each IC has numerous contacts 122 disposed about its periphery. The printer 108 (shown in broken lines) prints conductive traces 124 that electrically couple at one end to the contacts 122 of the IC 120, and extend to a longitudinal edge 125 of the print media 114. Each conductive trace 124 terminates at a free end at the longitudinal edge 125 with an electrical contact 126. The electrical contacts 126 are substantially larger than the contacts 122 of the IC 120 and permit the IC to be coupled to external circuitry at the electrical contacts 126 via the conductive traces 124.

Referring to Figure 3, an alternative embodiment to the print media 114 of Figure 2 lacks the embedded IC 120. As shown in Figure 3, the printer 108 instead prints the conductive traces 124 on a print media 130. In general, this alternative embodiment and those described in this application are substantially similar to previously described embodiments, and common elements and steps are identified by the same reference numbers. Only significant differences in construction or operation are described in detail.

As shown in Figure 3, the printer 108 prints each of the conductive traces 124 with the ends 132 positioned about a central space 134. An IC is then electrically coupled and secured to the print media 130 in the space 134. The print media 130 (and 114) is preferably of a flexible web- or sheet-type material having very low conductivity

(*e.g.*, sheet plastic), and which is heat resistant. Examples of suitable print media 130 include polyimide, poly-ether-ether-ketone, FR4, and other known substrates.

After printing the conductive traces 124 on the print media 130, known techniques can be employed to affix an IC to the print media, and electrically couple the IC to the conductive traces 124. For example, a conventional masking process can overprint or overlaminate an encapsulating mask layer over much of the conductive traces 124 and the print media 130, but leave exposed the ends 132 and electrical contacts 126. Another conventional process can silk-screen solder paste onto the ends 132, after which the IC is surface mounted to the print media 130 and electrically coupled to the ends by means of the solder paste. As a result, conventional techniques are employed to perform most of the steps in coupling an IC to a series of conductive traces on a substrate such as a circuit board.

Referring to Figure 4, an IC 120A is affixed within the space 134 by means of adhesive 136 applied to an underside of the IC. The IC is then placed within the space 134 so that the adhesive 136 secures the IC to the print media 130 within the space. Typical pick and place machinery or other automated apparatus (not shown) can automatically position the adhesive 136 on the underside of the IC 120A and position the IC in the space 134. Electrical contacts 138 extend downwardly from an underside of the IC 120A to contact the ends 132 of the conductive traces 124. The adhesive 136 ensures that the contacts 138 remain in electrical contact with the ends 132 of the conductive traces 124.

Referring to Figure 5, in an alternative embodiment, adhesive 136A is first positioned within the space 134, rather than on the IC 120A. Thereafter, the IC 120A is positioned onto an upper surface of the adhesive 136A, securing it thereto. Alternatively, the adhesive 136A can be previously formed on the print media 130. Under the embodiments of Figures 4 and 5, the adhesive 136 and/or 136A can be curable using ultraviolet light (UV) or be heat-fusible. Rather than employing downwardly extending electrical contacts 138 (Figure 4), the IC 120A in Figure 5 employs electrical contacts 140 that are substantially flush with an underside of the IC. The conductive traces 124, particularly the ends 132, can be slightly raised from the

space 134 so that the contacts 140 of the IC 120A form a constant electrical contact thereto when the IC is secured to the adhesive 136A. Alternatively, the IC 120A can be quickly affixed to the adhesive 136A after the ends 132 of the conductive traces 124 are printed, and while such ends are still "wet" (before they have fixed or dried). The ends 132 then dry to form a secure electrical contact with the contacts 140 of the IC 120A. In one alternative embodiment, the connection between the ends 132 of the traces 124 with the contacts 140 of the IC 120A are sufficiently secure such that the adhesive 136A is unnecessary.

Referring to Figure 6A, in yet another alternative embodiment, the IC 120 is positioned in electrical contact with the traces 124. An overlay 150 having an adhesive underside 152 is secured over the IC 120, conductive traces 124 and the print media 130, thereby securing the IC to the print media. In another alternative embodiment (not shown), the overlay 150 can be applied or affixed using other means, such as with vacuum forces or heat sealing in a "shrink-wrap" fashion over the print media 130 to secure the IC 120 thereto.

Referring to Figure 6B, the printer 108 prints the conductive traces 124, where the conductive traces are printed using a conductive material having adhesive properties. When the ends 132 of the conductive traces 124A have not yet cured, the IC 120 is positioned thereto so that the traces can cure and secure the IC (at its electrical contacts 138) to the print media 130. Alternatively, the conductive traces 124 can be cured using subsequent processing to their final non-adhesive state using conventional techniques, such as heat curing, UV curing, etc.

The printer 108 (via the computer 102) may print only select traces on any of the above-noted print media to thereby selectively couple only certain leads on an IC. As a result, some leads of the IC remain unconnected. In general, the conductive traces can be printed in standard configurations established by ISA, EISA, and known semiconductor chip in/out configurations. Alternatively, certain conductive traces can be preformed on the print media, such as traces configured under the EISA standard (Extended Industry Standard Architecture), where such traces are configured or treated to be abrasion resistant.

The resolution of the printer 108 is based on the type of print engine employed in the printer, as well as the applications to which the printer will be used. A higher density printer can print higher density circuits that correspond with reasonable tolerances to the attached IC devices.

The printer 108 can, of course, print more complex conductive traces than those shown in Figure 3. For example, an IC can employ a microball grid array, where an underside of the IC chip includes an array of conductive heat sensitive balls at terminals of the chip. The printer 108 prints desired conductive traces on the print media, to which the microball grid array are electrically coupled when the IC chip is secured to the print media.

<u>Security Card/Key Example</u>

Referring to Figure 7, another example of a product printable by the system 100 (Figure 1A) is a security card/key 160. The printer 180 prints several interconnected conductive traces 162 having terminal ends 164. Most traces share a pair of ends 164. For example, the conductive trace 162′ shares a first and fourth end terminal 164′, as shown in Figure 7. The security card/key 160 is then inserted into a reader (not shown) that electrically couples to the terminal ends 164. Based on a predetermined combination of conductive traces 162 coupled to terminal ends 164, appropriate conductive circuits are met in the reader.

Alternatively, one or more of the conductive traces 162 could have only a single end 164, and thereby not form a conductive circuit when coupled to the reader. Such an arrangement would provide for additional combinations for the security card/key 160. While clearly shown in Figure 7, the conductive traces 162 are not visible when the security card/key 160 manufacturing is completed. While the terminal ends 164 are shown positioned simply at a right-hand edge of the security card/key 160, the terminal ends can, in an alternative embodiment, be printed to electrically contact with terminal ends 166 (shown in broken lines). The terminal ends 166 could be preformed with a substrate 168, which forms a rigid base for the security card/key 160. The substrate 168 is preferably more rigid than the print media 114 (Figure 2).

The printer 108 can print not only the conductive traces 162 on the substrate 168 of the security card/key 160, but also additional information. For example, the printer 108 can print a picture 170 of the card's owner, as well as the owner's name 172 and ID number 174. Thus, the printer 108 of the exemplary embodiment can print pictures as well as alphanumeric text. Furthermore, the printer 108 can print machine-readable symbols, such as a bar code 176 and/or magnetic stripes on the substrate 168. Thus, the security card/key 160 forms also an identification badge for the user.

Print Media

The printing system 100 of the exemplary embodiment can print conductive traces and circuits for numerous applications, not simply for interconnecting ICs and for security cards/keys. One problem of printing conductive traces occurs when traces must overlap one another, but not be electrically coupled to each other. For example, the conductive trace 162′ cannot electrically contact with the other two conductive traces 162.

Referring to Figures 8A and 8B, one method of providing electric coupling between traces and permitting traces to "overlap" one another is to provide short, regularly spaced segments 180 of conductive material within a print media or substrate 182. Pairs of vias 184 extend through an upper surface of the print substrate 182 to expose opposite ends of each conductive segment 180. The printer 108 can then print conductive traces over the vias 184, where a portion of the trace extends down and electrically contacts with the conductive element 180, as shown as in broken lines as trace 186 in Figure 8B. Alternatively, a conductive terminal or plug can be preformed in the print media 182 that electrically couples to the conductive segments 180 and is flush with or extends upwardly from an upper surface of the print media (shown in broken lines as plug 188 in Figure 8B). The printer 108 then prints conductive traces which couple with the plug 188.

The printer 108 can print conductive traces in one direction (*e.g.*, vertically with respect to Figure 8A), while the conductive segments 180 extend

horizontally. One or more vertically extending conductive traces can thereby be electrically coupled together via horizontally extending conductive segments 180. In addition to conductive segments 180 having two vias, the segments can have a greater number of vias, such as a conductive segment 180A having three vias.

Referring to Figures 9A and 9B, an alternative embodiment to the print media of Figures 8A and 8B employs embedded conductive vias 190 in a print media 192. The print media 192 can be formed by a first substrate 192A having pre-formed holes therein. Aluminum foil dots or squares forming the conductive vias 190 are positioned over the holes. Then, an upper substrate 192B is applied over the top of the substrate 192A and the aluminum foil dots to capture the dots therein. The upper substrate 192A may not only be substantially similar to the substrate 192A, but be cast coated over, or a laminate formed over the substrate 192A.

While the conductive vias 190 are shown in Figure 9B as positioned offset from upper and lower surfaces of the print media 192, the vias could be formed to be flush with or extend outwardly from the print media. Unlike the print media 182 of Figures 8A and 8B, the print media 192 of Figures 9A and 9B requires conductive traces 186 to be printed on both sides of the print media. The vias 190 then interconnect traces extending on opposite sides of the print media 192. A printer capable of printing on both sides of the print media 182 is likely more expensive than a printer which prints on only one side of a print media.

The vias 190 (and 184) can be laid out in a variety of patterns in the print media 192 (and 182). The vias 190 are regularly spaced in the print media 192, and staggered in alternating rows, as shown in Figure 9A. Alternatively, as shown in Figure 8A, the vias 184 can be regularly positioned in aligned rows and columns. Various other patterns are possible, such as hexagonal patterns, where vias are positioned at intersecting vertices of interlocking hexagons.

If the printer 108 has a sufficiently sophisticated print media movement system (*e.g.*, employing a step or motor, tachometer, etc.) then the printer can accurately print conductive traces on the print media. However, to increase printing accuracy, or reduce the cost of the printer 108, the print media 102 can include tractor feed holes 194

positioned along opposite edges of the print media 192. The printer 108 then includes a tractor feed mechanism for accurately moving the print media 192 therethrough. Additionally, or alternatively, the print media 192 can include fiducials 196 that the printer 108 employs to optically align the print media within the printer. The fiducials 196 may be used by a pick and place machine to optically align an IC on the print media. The printer 108 can also print additional information, such as copyright or mask work notices, part numbers, patent numbers, part designators, etc.

Referring to Figures 10A and 10B, another alternate embodiment for a print media is shown having vias 200 formed through a print media 202, where such vias lack any conductive material therein. The printer 108 prints conductive traces 204 on an upper surface of the print media 202, where conductive ink extends down into one of the vias 200, as shown by a filled via 206. A disposable sheet or liner 208 is removably affixed to an underside of the print media 202. After the printer 108 prints the conductive traces 204 on an upper side of the print media 202, the printer or the user removes liner 208 to expose an underside 210 of the print media. The printer 108 then prints conductive traces on a reverse side of the print media 202, where such traces electrically couple to the filled vias 206. The printer 108 may need to employ a conductive ink on the reverse side of the print media 202 having a melting point lower than a melting point of a conductive ink used on the upper side of the print media, to thereby properly couple traces on opposite sides of the print media at the vias 200.

In an alternative embodiment similar to the print media of Figures 10A and 10B, a print media (not shown) can eliminate the liner 208 from the print media 202. The vias 200 are formed to have a size small enough, and the conductive material printed by the ribbon has a viscosity sufficient so that the printer 108 may print the conductive traces 204 over the via. The meniscus created by the conductive ink from the printer 108 is sufficient to extend within the via 200 without breaking or bleeding too far to the other side of the print media 202. The printer 108 can then print conductive traces on the opposite side of the print media 202 and be coupled to the previously printed traces at the vias 200.

The print media of Figures 8A-10B require the use of only a single print head in the printer 108 that prints only conductive ink (such as ink from a single ribbon). If the printer 108 is more sophisticated, such that it can print not only conductive traces, but also insulative or dielectric traces, then the printer can employ much simpler print media without having vias or conductive elements therein. The printer 108, instead, selectively prints insulative traces over conductive traces where a second conductive trace is to be formed over, but not electrically coupled to, the underlying conductive trace.

In another alternative embodiment (not shown), a print media includes conductive traces forming a grid or other pattern, where horizontal and vertical traces electrically connect to each other. The print head in the printer 108 selectively melts, vaporizes or otherwise breaks certain traces to form desired conductive trace patterns. In another alternative embodiment (not shown), a similar print media having interconnected, pre-formed conductive traces is provided to the printer 108, where the printer prints dielectric or insulative portions. The printer 108 thus selectively prints portions of dielectric material on the print media to selectively break connections between conductive traces.

In yet another alternative embodiment (not shown), the print media can include numerous, parallel horizontal and vertical conductive traces preformed on the print media, where a dielectric is positioned at the vertices of the traces, so that they do not electrically connect. The printer 108 then simply prints a conductive trace between desired horizontal and vertical conductive traces to interconnect them, or to selectively melt, vaporize or otherwise remove the dielectric positioned at a vertex to interconnect two traces. If a user desired to print only capacitive circuit elements (described below) or capacitively intercouple two conductive traces, the print media can be formed of a thin dielectric material. The printer 108 prints conductive traces on opposite sides of the print media, where such traces are aligned on opposite sides of the print media, at predetermined locations, to permit capacitive coupling between the traces.

Referring to Figure 28, another alternative embodiment for a print media suitable for coupling to ICs is shown as having pre-formed conductive pads 212 formed

along longitudinal edges of an elongated web-type print media 214 having non-conductive properties. Regularly spaced sets of lead pads 216 are pre-formed between the pads 212, and are arranged to form the central space 134 therebetween. For example, the print media 214 can be formed of plastic, where the pads 212 and 216 are pre-formed copper squares silk-screened and formed thereon. The printer 108 prints conductive traces 218 (shown in broken lines) to selectively couple the pads 212 with the lead pads 216. The printer 108 can include a cutter (not shown) that separates individual portions of the print media 214 (shown schematically as a broken line 219). An IC (not shown) can then be coupled to the lead pads 216 using conventional techniques (*e.g.*, surface mount leaded ICs, ball grid arrays, flip chips, or other technologies), while the pads 212 can be coupled to external circuitry using similar conventional techniques. By pre-forming the pads, and only printing conductive traces therebetween, the print media of Figure 28 eliminates any special materials problems that may arise with the materials employed by the printer 108 to print the conductive traces 218.

In another alternative embodiment for a print medium, the print medium is formed of a planar, insulative material having holes formed therethrough (not shown). The holes are preformed in the print media in an arrangement similar to the arrangement of leads on an IC. The printer 108 can print conductive traces from the holes to pads or other external circuitry. Pick and place machinery can then place an IC on the print media, with the leads extending through the holes. Thereafter, solder reflow, or other electrical coupling techniques can connect the leads to the traces at the holes.

Referring to Figures 29A and 29B, yet another alternative embodiment for a print media is shown having the embedded conductive vias 190 pre-formed and secured to the print media 192A, similar to the print media of Figures 9A and 9B. Unlike the print media of Figures 9A and 9B, the print media of Figures 29A and 29B lacks the print media layer 192B. Instead, the conductive vias 190 are formed as circular or square patches of conductive material (*e.g.*, aluminum or copper) that are positioned and secured about holes 195. The print media of Figures 29A and 29B may be more easily fabricated than the print media of Figures 9A and 9B.

Referring to Figure 30, two or more layers of print media may be secured together to form a multi-layer board, similar to a multi-layer printed circuit board. As shown in Figure 30, three layers of print media 240, 242, and 244 can be stacked and secured together so that selected portions of conductive traces 241, 243, and 245, printed by the printer 108, can be electrically coupled, respectively. For example, a conductive trace 241A electrically couples to a conductive trace 243A, which in turn electrically couples to a conductive trace 245A, when the print media layers 240, 242, and 244, respectively, are stacked and secured together.

Printer and Ribbon

Referring to Figure 11, the print media 114 passes through the printer 108, which contains three separate thermal print heads 250, 252 and 254 that each transfer "ink" from spools of a respective ribbon 256, 258 and 260 to the print media. Unlike a conventional printer, in the printer 108, one or more of the ribbons 256, 258 and 260 contains a conductive ink or pigment. In the embodiment of Figure 11, the first and third ribbons 256 and 260 contain conductive ink while the second ribbon 258 contains a dielectric ink having a very low conductivity. The ribbon containing conductive ink may be formed in a variety of fashions, such as by suspending metallic particles in a thermally active base. As generally used herein, "ink" refers to one or more compounds transferred by the printer 108 to a substrate or print media, where such compound has a desired electrical property, *e.g.*, conductive, insulative, resistive, charge-enhanced, charge-depleted, etc. The ink may require a post printing step for the ink to achieve its desired properties (*e.g.*, UV curable to a fixed yet conductive state).

Referring to Figure 12, a ribbon 220 has a carrier layer 222 releasably fixed to a print layer 224 by means of an interposed release layer 226. The carrier layer 222 can be sheet plastic, such as polyester (having a thickness of, for example, 4.5 microns), or polyester terepthalate (PET). The print layer 224 includes a fusible matrix with embedded conductive particles 227, where the matrix has a low resistivity, or a solvent coated pigment layer typical of current resin ribbons, but where the pigment layer is electrically conductive. The print layer 224 can be formed using thick film

methods, which are conventional in the microwave hybrid elements environment. The print layer 224 is selectively released, such as by heat, from the carrier layer 222 by means of a thermal print head 228 in the printer. The release layer 226 is, for example, a low melting point wax, having a thickness of approximately 1 micron.

In an alternative ribbon embodiment similar to that of Figure 12, the print layer 224 employs an anisotropically conductive adhesive comprised of a nominally non-conductive hot melt adhesive matrix loaded with conductive particles such as silver, aluminum or carbon particles. Each particle may have an effective diameter that is large relative to the operational thickness of the print layer 224, *i.e.*, relative to the thickness of the layer after transfer and when in use. The print layer 224 has its own hot melt adhesive properties, such that a separate adhesive layer is unnecessary (as described below). Instead, the matrix provides sufficient hot melt adhesive properties for the conductive particles 227 carried therein.

In another alternative ribbon embodiment similar to Figure 12 (not shown), the print layer 224 does not carry embedded conductive particles 227, but is instead itself conductive or non-conductive (insulative). The composition of the print layer 224 includes not only the desired electrical properties, but also sufficient hot melt adhesive properties to be released from the carrier layer 222 by the print head 228 and secured to the print media 114.

Referring to Figure 13A, an alternative ribbon embodiment employs a metal layer 230 releasably secured to the carrier layer 222. A thin fusible conductive adhesive layer 232 is secured over the metal layer 230, where these layers have thicknesses of approximately 2 and 3 microns, respectively. The adhesive layer 232 is heavily doped with a conductive material such as silver, copper, conductive carbon, etc. The thermal print head 228 selectively fuses the conductive adhesive 232 onto the print media and selectively melts the release layer 226. When the carrier 222 is removed from the print media, selected portions of the metal layer 230 remain fused to the conductive adhesive 232 on the print media, and are released from the carrier layer 222. One example of a ribbon having conductive ink was introduced in the mid-1980s by

Mitsubishi, which had vaporized metal films on a carrier layer for thermal transfer printing of decorative marks.

Referring to Figure 13B, another alternative ribbon embodiment is similar to the ribbon of Figure 13A. A ribbon 350, shown in Figure 13B, includes a metal film layer 352 formed using vacuum deposition, electroplating, or metal sputtering techniques over the release layer 226. An anti-static back coding 354, having a thickness of approximately 0.2 microns, is formed on a back side of the carrier layer 222.

The conductive, resistive, semi-conductive or other properties of the ink in the ribbons described herein may be of materials, and manufactured by techniques, disclosed in R. Brown, *Materials and Processes for Microwave Hybrids*, published by the International Society for Hybrid Electronics, 1991, incorporated by reference herein. Those skilled in the relevant art can construct the various ribbons described herein using numerous methods, such as by adapting techniques explained in this book. For example, a matrix of metal or conductive particles can be "frit" bonded with glass or another agent and then secured to a substrate. Other techniques of suspending metal particles include mixed bonded conductors and reactively bonded conductors, both formed over a substrate such as the carrier layer 222. Many of these described techniques for securing metal particles in a matrix include firing or heating the particles with glass or another material to form the print layer 224.

Techniques for fabricating the inventive ribbons include providing a roll of the substrate material for the carrier layer 222, which is fed through rollers that apply ink or conductive material. Thereafter, a drying or cooling process is performed and the finished roll is wound downstream from the supply roll of the substrate.

Bulk and thick film conductive materials, each having different resistivities, include silver, copper, gold, aluminum, tungsten, molybdenum, nickel, platinum, chromium, tantalum, and palladium. Some conductors, such as chromium, tantalum and titanium, typically have excellent adherence to dielectric materials, such as the carrier layer 222 or the release layer 226, but have low conductivity. Tungsten and molybdenum have moderate conductivity and good adherence to such dielectrics,

while aluminum has a high conductivity but only fair adherence to such dielectrics. High conductors such as gold, silver and copper typically have poor adherence to such dielectrics. An appropriate primer layer may be necessary between a layer of such high conductors and the carrier layer 222.

Referring back to Figure 11, while the print heads 250, 252 and 254 in the described embodiment are thermal print heads, which employ corresponding thermally activated ribbons, a variety of other types of print heads, such as ink jet print heads, may be within the scope of the invention. The printer 108 can also employ other known print engines that can be modified based on the detailed description of the invention provided herein. Such print engines include magnetographic, electrostatic, piezoelectric, or ink jet print engines. For example, with electrostatic or xerographic printing, a conductive "toner" is employed having a thin insulative layer vaporized or formed over each toner particle. During fusing of the toner particles, the insulator material is vaporized leaving only the conductive material.

Alternatively, the invention can employ impact print engines, such as dot matrix or formed character print engines (*e.g.*, daisy wheel print engines). As is known, the mechanical force produced by impact print engines releases ink from a ribbon. Under an alternative embodiment of the invention, the printer 108 includes an impact print engine that releases conductive, dielectric or other ink from a ribbon. Therefore, while the printer 108 is described in the exemplary embodiment as employing a thermal print engine, various other printing technologies are within the scope of the invention.

As the print media 114 travels through the printer 108 in the direction indicated by an arrow 262, respective platen rollers 264 press the print media 114 and ribbons 256, 258, and 260 against the respective print heads 250, 252, and 254. As the print media 114 passes each of the print heads 250, 252, and 254, print logic 270 activates each of the print heads 250, 252, and 254 to print various layers on the print media 114. The print logic 270 is of a conventional type of controlling print heads according to a predefined printing pattern, although the print logic 270 may include three separate sections, each dedicated to a respective print head 118, 120, 122. Print logic for printing multiple layers of inks is well known in multicolor printing. Those

skilled in the relevant art can modify such conventional print logic for use in the printer 108 based on the detailed description of the invention provided herein.

A pattern for printing on the print media 114 is established according to conventional layered mask approaches (*e.g.*, as in the semiconductor art) and stored as a digital or graphic data structure in a memory 272 of the printer 108. Alternatively, the printing pattern can be stored in memory (not shown) within the computer 102 (Figure 1). The printing pattern can be structured as a bit map image stored in the memory 272, or a vector-based image. The stored data is then applied to respective print drivers 275 that drive the respective print heads 118, 120, 122 with electrical signals responsive to the stored data. In response to the electrical signals, current passes through selected print elements, thereby providing heat.

Referring to Figure 31, a more detailed description of printing conductive traces using the ribbon 350 of Figure 13B will now be described. The carrier layer 222 effectively transports the ribbon 350 across the print head 228 and particularly across one or more print head heating elements (one of which is shown as a dot 360). Under control of the print logic 270, the dot 360 heats quickly to a temperature hot enough to drive transient heating of the ribbon structure during a scan line time. Preferably, the dot 360 heats to 350°C over a period of 100 to 200 microseconds, maintains the temperature for 150 to 250 microseconds, and then cools to a temperature below 70°C during the remainder of the line scan time. For a 16 dot per millimeter print head and a 4 inches per second print speed, this cooling period is preferably 250 to 400 microseconds. Importantly, the printer 108 creates a high heating rate and short pulse to minimize heat sinking and heat spread through the metal layer 352.

During heating, the print logic 270 causes the adhesive layer 232 to be held in intimate contact with the print media 114. A heat pulse wave front moves from the dot 360 of the print head 228, through the coating 354, carrier layer 222, and through the release, metal and adhesive layers 226, 352, and 232. The adhesive layer 252 becomes tacky and adheres to the print media 114. Simultaneously, the release layer 226 becomes weak, loosening the adhesion of the metal layer 352 to the carrier

layer 222. The ribbon 350 and print media 114 are sequentially stepped or indexed one line width past the print head 228 by the platen roller 264 riding against an underside or far side of the print media. Optional pinch rollers 364, and ribbon transport rollers 366 and 368, move the print media 114 and ribbon 350 in synchronism between each line width. The process of holding the ribbon against the print head 228 and incrementing the print media 114 and ribbon 350 for a step or indexed line width is repeated. As a result, the metal layer 352 becomes more strongly adhered to the print media 114 than to the ribbon carrier 222 in a pattern corresponding to the repeated heating and stepping of the ribbon 350 and print media.

At roller 368, also known as a strip point, the ribbon 350 is peeled, preferably at a high angle of 90 degrees or more, away from the print media 114. The roller 368 is preferably positioned ¼ to ¾ inches down stream from the print head 228 and platen roller 264. The peeling results in heated portions of the metal layer 352 adhering to the print media 114 in a pattern corresponding to the selective heating of dots in the print head 228. The remainder of the metal layer 352 is removed with the carrier 222 and subsequently rewound on a take-up reel (not shown) of the ribbon 350. A pattern of metal or conductive material left adhering to the print media 114 forms a conductive trace or pattern. More details regarding thermal printing may be found in, for example, U.S. Patent Nos. 5,625,399, issued April 29, 1997 and 5,548,688, issued August 20, 1996, both assigned to the assignee of the invention.

If other layers are to be printed using the print head 228, the print logic 220 causes the platen roller 264 to be removed from tight contact with the print media 114. This reduces pressure between a print media 114 and the ribbon 350, allowing them to slide against one another. The pinch rollers 364 retract the print media 114 to an index point while the rollers 366 and 368 hold the ribbon 350 at its current position, or moves the ribbon to another index point. The print logic 270 then causes the platen roller 264 to be placed into pressure contact with the print media 114, and against the ribbon 350 and print head 228. The printing process is performed again as noted above, and the printing is repeated so as to form an insulating pattern, second conductor, resistive pattern, magnetic pattern, light absorbing (printing) pattern or other pattern

according to the sequential information of desired traces and elements to be formed, and desired regions of a ribbon, to be formed on the print media 114. As noted herein, the digital images of traces and elements to be printed, and the particular material (ribbons) to form such traces or elements, are stored in the memory 272.

Referring to Figure 14, a printer 280 according to an alternative embodiment replaces the print heads 250, 252, and 254 with a single print head 282 and the ribbons 256, 258, and 260 with a single ribbon 284 having three parallel sections 286, 288, and 290. The first section 286 contains a conductive ink as indicated by the symbol σ. The second section 288 includes a dielectric ink such as wax as indicated by the symbol ε. The third section 290 includes a high permeability ink such as in Magnetic Ink Character Recognition (MICR) ink (produced by Deluxe Data Systems, NCR or AT&T) as indicated by the symbol μ.

To print conductive traces, the print head 282 and print media 114 are aligned to the first conductive section 286 and, as the print media 114 is transported past the print head 282, selected print elements are activated to transfer the conductive ink to the print media 114. Similarly, to print the dielectric material, the print media 114 and print head 282 are aligned to the second dielectric section 288 of the ribbon 284 and the print elements are activated to transfer the dielectric ink to the print media 114. Likewise, to print the high permeability material, the print head 282 and print media 114 are aligned to the third high permeability section 290 of the ribbon 284, and print elements are activated to transfer the high permeability ink to the print media 114. The high permeability material is used in conjunction with the dielectric and conductive traces to form known planar or layered inductive elements, such as inductors and transformers, as described below.

Alternatively, or in addition to the three sections 286, 288 and 290, the ribbon 284 can include N- and P-type sections for printing active devices (*e.g.*, transistors). N- and P-type material can be employed with a doped acrylic polymer, where the N- and P-type material is produced from known sources. For example, charge transmission layers (CTLs) used with charged generation layers (CGLs) in organic photoconductors (OPCs) can provide such materials. To print optoelectronic

devices, the ribbon 282 can include zinc oxide or sulfur compounds having photoreactive qualities. To produce piezoelectric devices (*e.g.*, speakers, microphones, etc.), piezoelectric material having its crystal matrix properly aligned with the ribbon 284 can be provided. Resistive circuit elements and carbon microphones can be printed with the printer 108 where the ribbon 284 includes a carbon ink section. Furthermore, to print batteries, the ribbon 284 can include a lithium polymer to produce lithium polymer batteries. Various chemicals and materials necessary for producing circuit elements can be deposited on a substrate using vapor deposition techniques or other known techniques to form the ribbon 284.

The print head 282 and print media 114 move transversely or laterally with respect to the ribbon 284. Such lateral movement can be achieved either by moving the print head and print media relative to the ribbon, or by moving the ribbon 284 laterally relative to the print head 282 and print media 114. A variety of lateral motion mechanisms are known in the art and are commonly found in multicolor printing systems. In an alternative embodiment, the print head 282 has three portions, where one of each of the portions is positioned adjacent to one of the three sections 286, 288, and 290 of the ribbon 284 (shown in broken lines as print head 282A). As a result, the print head 282A need not move with respect to the ribbon 282; only the print media 114 must move with respect to the print head 282 and the ribbon 284. The ribbon 284, of course, moves in all embodiments to provide fresh (unprinted) sections for activation by the print head.

The ribbon 284 of Figure 14 is shown as constructed of having first, second, and third sections 286, 288, and 290 extending longitudinally between two spools (not shown) and parallel to a carrier layer (not shown). Referring to Figure 15, a ribbon 284A in an alternative embodiment positions the first, second, and third sections 286, 288, and 290 transversely with respect to the carrier layer (not shown) that extends longitudinally between a pair of spools 294. The first, second, and third sections 286, 288, and 290 form a repeating pattern, as shown in Figure 15. Referring to Figure 16, a ribbon 284B in another alternative embodiment positions first, second, and third sections 286, 288, and 290 as layers that extend both longitudinally and transversely

with respect to a carrier layer 296. As a result, the first, second, and third sections 286, 288, and 290 form layers over the carrier layer 296.

To improve certain electrical characteristics of printed circuit elements, the printer 108 can operate in various environments. For example, the printer 108 can include an electrically activated magnetic field so that the printing of inductive or magnetic material within the magnetic field will cause the magnetic poles in the ink to align with the magnetic field. Additionally, to aid in the transfer of certain materials that could deteriorate in an oxygenated environment, or which may be otherwise contaminated, the printer 108 can operate within a vacuum environment. Those skilled in the relevant art will readily recognize based on the detailed description provided of the invention that the printer 108 can operate in other environments to provide other desired characteristics of printed circuit elements.

Remotely Readable Tag Example

The printer of Figure 11 can print not only conductive traces, but also interconnected circuit elements to form electrical circuits. One example of such a circuit is an RF readable tag. RF readable tags are typically used for tracking and providing information about items to which they are affixed. Such devices receive an RF signal and, in response, output a reply RF signal. In some applications, the RF tag is a passive tag that simply retransmits the input signal or a filtered version of the input signal. Such devices do not require batteries; however, such devices typically can retransmit only a very limited amount of information and provide a very low power reply RF signal. An alternative RF tag includes a power source, such as a battery that drives an active RF transmitter. In response to an RF request or polling signal, the active RF tag retrieves data from a memory and outputs the data through a reply RF signal.

Referring to Figure 17, an exemplary embodiment of tag 300 has two primary components, a symbol 302 and a remotely accessible memory 304, both carried by a print media 306. The print media 306 is a substantially planar platform upon which the symbol 302 is printed and upon which conductive traces are also printed, in a

manner which will be described below with reference to Figures 19-21. The print media 306 can be adapted for repeatable attachment to and detachment from various target objects using known attachment means, such as a common adhesive or a hook-and-loop structure such as Velcro™, so that the tags 300 are reusable. The print media 306 is preferably formed from a flexible material, such as a conventional organic polymer, to allow the tag 300 to conform more easily to the target object. However, one skilled in the art will recognize that, for some applications, a more rigid material such as a ceramic substrate may be desirable. In other applications, the print media 306 may be made of a paper or other flexible material, or be disposable.

The symbol 302 is a pattern of regions of varying reflectance on an exposed portion of the print media 306 that reflects some of the light from an illumination source back toward a reader. Numerous types of symbologies are known and may include bar codes such as UPC/EAN, Code 39 and Code 93, "multi-row" or "stacked" symbologies such as PDF-417 and Code 49, and "area" symbologies such as Code One. A bar code is the symbol 302 illustrated in Figure 17, which includes individual symbol characters 308. The symbol 302 can uniquely identify the tag 300 and/or provide information about the tag, such as information stored within the remotely accessible memory 304. The machine-readable symbol 302 can encode information, such as tag identification data necessary for appropriately interfacing with the memory 304. As explained herein, human readable information, such as alphanumeric characters, can also be printed on the tag 300.

The remotely accessible memory 304 is an RF readable and writeable memory device positioned adjacent to the symbol 302 on the print media 306 and is presented in block diagram form in Figure 18. The memory 304 includes a memory device 310 having its housing grounded, a receiver 312, a power source 314 such as a battery, and a transmitter 316. The memory device 310 in this embodiment is a serially readable, single-wire memory device, such as one of the DS199x series of Touch Memory™ devices from Dallas Semiconductor. Such devices have a single terminal used for data input and data output as well as power input. The housing of the memory device 310 is grounded through conductive traces 318 to provide a signal reference. A

microprocessor (not shown) within the memory device 310 controls data transfer and electrical operation of the memory device 310 in a manner known in the art, using a manufacturer-identified protocol.

The receiver 312 is coupled to the memory device 310 and the power source 314 through the conductive traces 318 to provide input to the memory device 310. The transmitter 316 is a conventional transmitter, including an RF antenna 320, and is also coupled to the memory device 310 through the conductive traces 318. The power source 314 is connected through the traces 128 to provide power to the memory device 310, receiver 312, and transmitter 316. The antenna 320 can be of various patterns to match a particular application. Various antennas are discussed below. Formation of the traces 128 and the RF antenna 320 will be described below with reference to Figures 19-21.

While the embodiment of Figures 17 and 18 employs a battery as the power source 314, other types of power sources are within the scope of the invention. For example, solar cells may be used where expected lifetime of the battery 314 is inadequate. The relatively large area of the symbol 302 and the generally planar structure of the print media 306 allow the solar cell to be integrated easily into the tag 300. Also, in some embodiments, the tag 300 may be passive. In such an embodiment, the memory device 310 may be replaced with a passive RF device, such as is commonly found in department store security tags.

Referring now to Figures 19-21, formation of the tag 300 based on the printer 108 of Figure 11 will now be described. The first ribbon 256 carries a conductive thermal ink that transfers to the print media 114 when activated by heat from print elements in the print head 250. The ink transfers to the print media 114 and forms the set of conductive traces 318 as shown in Figure 19. The first print head 250 also prints the antenna 320 as a conductive patch.

The print media 114 travels from the first print head 250 to the second print head 252 where the second print head transfers ink from the second ribbon 250 to the print media 114, as shown in Figure 20. In three regions 330, 332, and 334, the dielectric ink forms an insulative layer. The first dielectric region 330 extends between

two of the traces 318 and includes a pair of vias 336 that expose small portions 338 of the respective traces 318. The second region 332 covers a section of one of the traces 318, and in the third region 334, the dielectric covers a section of the print media 114.

In a separate region 340, the dielectric ink forms the machine-readable symbol 302, which is shown as a bar code symbol. The second ribbon 120 contains a dielectric ink having a low optical reflectivity. If the dielectric ink has a low reflectivity, then the print media 114 has a high reflectivity, to provide contrast between the bars printed by the dielectric ink and the spaces therebetween of the print media, which together form the machine-readable symbol 302. One skilled in the art will recognize that the symbol may be a human-readable symbol or any type of machine-readable symbol, such as a two-dimensional or layered symbol. A wide variety of such symbols are known in the art.

After the dielectric regions 330, 332, 334, and 340 are printed, the print media 114 travels from the second print head 252 to the third print head 254 where the third print head activates the third ribbon 260 to transfer a conductive ink to the print media 114, as shown in Figure 21. A portion of the conductive ink from the third ribbon 260 covers an upper region 344 that overlays the dielectrically coated region 332. Because the dielectric material in the region 332 electrically isolates the conductive region 344 from the traces 318, the upper region 344 can cross over the lower traces 318 without forming an electrical connection.

Over the second dielectric region 334, a second conductive trace 346 is formed by the third print head and ribbon, which connects two of the traces 318 without contacting the print media. In a similar fashion, the third print head 254 forms a conductive trace 348 that overlays the region 330 and the vias 336. Within the vias 336, the trace 348 contacts two of the traces 318. The trace 348 thus forms an insulated interconnect that is isolated from the print media 114 by the dielectric region 330. One skilled in the art will recognize that although no conductive traces 318 are shown below the second dielectric region 334, such an interconnect structure typically extends across conductive traces or other electrically active areas of a substrate, such as the print media 114.

When the print media 114 leaves the printer 108, all desired conductive traces and dielectric region and symbol 302 have been printed. The memory 304 is then bonded to the print media 114 in a conventional fashion, such as with a conductive epoxy, to couple to ends of certain traces. In an alternative embodiment, the print media 114 includes a die cut aperture or indentation within which the memory 304 is positioned. The memory 304 could be removably secured within such an aperture or indentation in the print media 114. If the tag 300 is to be positioned on a device that can cause electromagnetic interference, such as a metal object, then the print media 114 can include a foam or other insulative backing to raise the memory 304 away from a surface of the object on which it is fixed.

In an alternative embodiment, conductive regions can be printed on both sides of the print media 114 and thereby be electrically separated. If a given element or trace is to be coupled to another trace/element, such traces/elements can be capacitively coupled together, through the print media 114. As a result, the dielectric regions need not be formed.

The print logic 270, in an alternative embodiment, can print a series of unique tags 300 based on appropriate software. The printer 108 encodes or stores data in each memory 304 using, for example, an RF transmitter (not shown). Alternatively, the printer 108 can selectively make conductive connections in preformed or printer-formed trace patterns for each of the tags 300 to selectively encode information in the memory 304. Alternatively, the printer 108 can melt, vaporize or otherwise break connections in conductive traces to thereby encode information within the memory 304 of the tag 300. Pick and place machinery (not shown) can then extract each tag from the printer 108 and affix it to appropriate objects, such as objects on a conveyor belt.

<u>Printable Circuit Elements</u>

As shown in Figure 21, the RF antenna 320 is formed essentially as a patch so as to provide maximum omnidirectionality for the RF antenna. Other types of antennas can be created by the printer 108. For example, the printer 108 can print a loop-type antenna on the print media 114 to provide moderate, short range,

omnidirectionality while providing noise rejection. A bipolar antenna can similarly be created to increase RF communication range, with appropriate tuning, but be directional. Furthermore, multiple, tuned antennas can be used to select the maximum sensitivity to discrete frequencies and multiple antennas can be created for diversification. The printer 108 can also print two closely-spaced non-uniform antennas to provide a detuning device. The wavelength and sensitivity of the antenna can be tuned by varying the printed length of the antenna.

Referring to Figure 22, three resistors 402, 404 and 406 are shown. The resistor 402 is preferably printed using a resistive ink, such as carbon, whereby a greater concentration at a middle of the resistor results in a reduced resistivity for this resistor. The resistor 404 is preferably printed with a conductive material having a greater conductivity than carbon. A greater resistance is obtained by providing a narrow current channel or path at a middle of the resistor 404. The resistor 406 can be printed with a resistive or conductive material. The resistance for the resistor 406 is derived by providing a long current path (shown as a serpentine path in Figure 22) for this resistor. Other geometries are possible for printed resistors, as well as various printed materials for providing various resistance values. For example, the printer 108 can vary the printed thickness of a resistive element to modify the resistance thereof.

Referring to Figure 32, various resistive values for printed resistors may be obtained by employing a ribbon 490 having regions of differing resistivity. For example, the ribbon 490 can include regions 492, 494, 496, and 498 having resistance values of 10 ohms, 100 ohms, 1,000 ohms and 10,000 ohms, respectively. The printer 108 prints a resistive element using one or more of the regions 492, 494, 496 or 498 to provide a desired gross resistive value. The printer 108 also varies the thickness or size of the printed resistor to trim a given resistive element to a desired resistance value.

Referring to Figure 33, a printer 500 is shown as having printed resistive elements 502 and 504 on the print media 114. The printer 500 includes a pair of probes 506 and 508 that are biased to contact the print media 114 as it exits the print head. In particular, the probes 506 and 508 contact conductive traces 116 at opposite ends of the printed resistors 502 and 504. A measuring circuit 510 is coupled to the probes 506 and

508, and measures an electrical characteristic of printed elements, and can output such measured characteristic to the print logic or a central processing unit (CPU). The measuring circuit 510 of the printer 500 can thereby measure, for example, the resistance of the resistive element 502 after it has been printed. If the resistance value of the resistive element 502 is less than desired, the printer 500 can retract the print media 114, and print additional resistive or conductive material for the resistive element 502 to thereby modify its resistance value to a desired value.

Referring to Figure 23, two capacitive elements are shown formed on a substrate 410. A substantially square conductive patch 412 is first formed on the substrate 410 and forms one plate of both capacitors. The first plate 412 either can be pre-formed on the substrate 410, or be initially printed by the printer 108. A terminal 414 coupled to the plate 412 is coupled to a voltage potential or source (not shown). A square dielectric patch 416 is then formed over the first plate 412. A second plate 418 of one capacitor is formed as a small patch over both the dielectric patch 416 and the first plate 412. In another region of the dielectric patch 416, a second plate 420 of the other capacitor is formed, which is also positioned over another portion of the first plate 412. The second plates 418 and 420 are coupled to other circuitry by terminals 422 and 424, respectively. As shown in Figure 23, the second plates 418 and 420 have differing areas, and thereby provide differing capacitances. A low capacitance value capacitor can also be formed as two parallel lines of conductive material having a space or dielectric printed therebetween (not shown).

The capacitances of capacitive elements printed by the printer 108 can also be varied by changing the thickness and dielectric substance of the dielectric patch 416. Similarly, the printer 108 may vary the capacitance values of printed capacitive elements using techniques described above for resistive elements. Likewise, the printer 500 can measure the capacitance of printed capacitive elements (and other elements) using the printer 500.

Inductive elements can also be printed by the printer 108 using conventional semiconductor fabrication topologies for patterning inductors, transformers and other inductive elements. Referring to Figure 24, varying resistive,

capacitive and inductive values can be achieved by providing a parallel series of elements printed by the printer 108. For example, Figure 24 shows four elements 430, 432, 434 and 436, which can be, for example, resistive elements. An input conductor trace 438 (shown in broken lines) couples to an input terminal of both of the resistive elements 430 and 432, while a conductive trace 440 is coupled to the outputs of each of these elements. Alternatively, an input conductive trace 442 is coupled at an input of the third resistive element 434, while an output conductive trace 444 is coupled to an output of the fourth conductive element 436. A conductive trace 446 then couples to the free ends of the third and fourth resistive elements 434 and 436. As a result, the first and second resistive elements 430 and 432 are coupled in parallel, while the third and fourth resistive elements 434 and 436 are coupled in series, thereby providing classic parallel and series resistance for the pairs of resistive elements 430 and 432, and 434 and 436. Those skilled in the art will recognize that the printer 108 can print other patterns for various impedance elements and provide various interconnections therebetween to provide varying resistive, capacitive and inductive values.

Referring to Figure 25, the printer 108 can print not only passive devices, but also active devices. For example, the printer 108 can print a PNP transistor by first depositing an N-type layer 450 on the substrate 410. The printer 108 then prints P-type layers 452 and 454 over the N-type layer 450, with a dielectric layer 456 printed and positioned therebetween. Finally, the printer 108 prints conductive material to form source and drain electrodes 458 and 460, with a gate electrode 462 positioned therebetween, positioned over the P-type layers 452 and 454, and the dielectric layer 456, all respectively. By combining numerous transistors, such as those shown in Figure 25, coupled with numerous capacitors, such as those shown in Figure 23, the printer 108 can print an array of memory cells, using a topology similar to that with semiconductor memory devices.

The printer 108 can also print NPN type transistors, as well as diodes and other active devices, such as CMOS, IGBT, MOSFET and other transistors. By varying the sizes and materials comprising the various P- and N-type regions, the characteristics of the transistors and other active devices can be correspondingly altered

to provide desired characteristics. In general, the system 100 can vary the thickness of any printed layer by, for example, providing several ribbons, or a single ribbon with different regions, where each ribbon/region has a different thickness of ink. Alternatively, the printer 108 can provide a ribbon with a uniform layer of ink, but the printer prints over the same region numerous times to provide increased layers of ink in the desired region.

Referring to Figure 26, the printer 108 can print input devices, such as the input devices 104 for the computer 102 (Figure 1A). A capacitive switch 470 is constructed in a manner similar to the capacitor as described above with respect to Figure 23. A single large second conductive plate 472 is positioned over the dielectric 416 and the first plate 412. Unlike the capacitors of Figure 23, the capacitive switch 470 of Figure 26 preferably employs a very thin dielectric for the dielectric layer 412, and substantially larger first and second plates 412 and 472, so that the switch can be operated by a human finger. The printer 108 or another device can print or position over the switch 470 a protective layer 474. The printer 108 can then print with standard ink or other material a digit 476 or other alphanumeric text.

While only a single capacitive switch 470 is shown in Figure 26, the printer 108 can print an array of such switches to form a keypad or keyboard. Similarly, by substantially reducing the size of each of the capacitive switches 470, the printer 108 can print a condensed array of such capacitive switches to form a sense detector, such as a thumbprint detector. Likewise, a matrix of capacitive switches provided in a rectangular array can operate as a position sensing input device for the computer 102 (*e.g.*, a cat).

Referring to Figure 27, the printer 108 can print not only input devices but also output devices. By employing an electroluminescent ink, the printer 108 prints seven segments 480 forming a conventional seven-segment output (*i.e.*, an "8" pattern). Each of the electroluminescent segments 480 is coupled to ground (not shown) and activated by a conductive electrode 482 (shown in broken lines). The printer 108 then provides a protective layer (not shown) printed over the electroluminescent segments 480. The printer 108 can print a one- or two-dimensional array of the

electroluminescent segments 480 to provide a display panel. Since the printer 108 can print active devices, the printer can print light-emitting diodes, in addition to electroluminescent displays.

The printer 108 can also print power sources. For example, the printer 108 can print flat batteries. Using known chemical compositions for lithium polymer batteries, the printer 108 can be adapted to provide such materials in alternating layers to provide batteries of various voltages. By employing photoreactive materials, the printer 108 can also print to solar cells. The printer 108 can also print temperature sensing devices. For example, if the conductive ink in the ribbons 256 and 260 (Figure 11) contained dissimilar conductive material, then the printer 108 can print bimetallic devices. As is known, such devices provide changing output in response to temperature changes.

Referring to Figure 34, a cross-section of a ribbon 520 for printing batteries is shown. A lithium polymer layer 522 is formed over the carrier layer 222. A conductive layer 524 is then formed over the layer 522. The conductive layer has sufficient hot melt adhesive properties to avoid the need for a separate adhesive layer. The layers 522 and 524 may be released simultaneously from the carrier layer 222 (possibly with the aid of a release layer (not shown)) and secured to a suitable print media to form a battery. The layer 522 forms the anode, while the layer 524 forms the cathode. Another ribbon structure (not shown) for manufacturing a battery and transferring such layers intact include the following layers in order: a positive electrode layer (conductor), a positive current collector layer, a solid polymer electrolyte layer, a negative current collector layer, a carrier layer, a release layer, and a negative terminal layer (conductor). Additionally, a ribbon may be made using appropriate layers to form nickel cadmium and nickel metal hydride (NiMH) batteries under aspects of the invention.

Referring to Figure 35, a cross-section of an alternative ribbon 530 provides several layers that are transferred substantially intact. A reflective layer 532, composed of aluminum or another conductive metal, is formed over the carrier layer 222. A layer 534 of a light-emitting material is then formed over the layer 532.

Another layer of aluminum 536 is applied over the layer 534, and a hot melt adhesive layer 538 is then formed over the layer 536. The layer 536 may also be composed of an optically transparent conductor. Upon proper activation of the print head 228, the layers 532, 534, 536 and 538 are released from the carrier layer 222 and secured intact to a single print media to form a light-emitting element such as a laser or LED.

The light-emitting material in the layer 534 may be constructed of light-emitting polymers, such as those developed by Dow Chemical Company. Other light-emitting polymers and monomers are available from such companies as Cambridge Display Technologies Ltd., and Pioneer Electronics Corp. Alternatively, organic light-emitting films may be employed, which may be spin coated as one layer over a layer of a transparent conductor such as indium tin oxide.

In addition to the ribbons described above, various additional materials may be employed to provide numerous electrical devices. For example, conductive polymers such as polypyrrole, polyphiophene and polyaniline may be employed and be particularly advantageous for adhering to typical carrier layers 222 used in ribbons.

Although specific embodiments of, and examples for, the present invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as will be recognized by those skilled in the relevant art. For example, although the embodiment is described herein as including three print heads 250, 252, and 254, fewer or more print heads may be desirable for some applications. The printer 108 can include traditional ink to print the symbol, image and human readable characters in Figure 7. Also, although the print heads 250, 252, and 254 are described herein as thermal print heads, as noted above, other types of print heads and print engines are within the scope of the invention.

The inventors envision creating low cost semiconductor-type circuits, such as semiconductor-type memories by employing a transferable ink having appropriate N-type and P-type dopant materials to thereby produce transistors. The printer 108 can then produce transistor structures using known semiconductor processing techniques. However, standard lithography, such as wet and dry etching, chemical-mechanical planarization, and other semiconductor manufacturing steps are

avoided. In addition to semiconductor-like circuits, surface acoustic wave devices can also be positioned on the tag 300 and form part of the memory 304.

Overall, the method and apparatus of the invention are not limited to printing conductive traces, security cards/keys and remotely readable tags, but can be applied to creating other electrical circuits. The various inventive teachings disclosed herein can be combined and/or modified to provide additional embodiments of the invention. These and other changes can be made to the invention in light of the above detailed description. In general, in the following claims, the terms used should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims, but should be construed to include all method and apparatus for forming electrical circuits. Accordingly, the invention is not limited by the disclosure, but instead its scope is to be determined entirely by the following claims.

CLAIMS

We Claim:

1. A system for printing electrical circuits comprising:

a computer having memory, an input device and a display screen, wherein the memory contains program instructions for the computer to (a) receive instructions input by a user through the input device to create an electrical circuit, (b) display on the display device a graphical representation of the user created electrical circuit, and (c) provide print instructions that represent the user created electrical circuit; and

a printer coupled to receive the print instructions from the computer, wherein the printer includes a print engine for printing the electrical circuit on a print media using a conductive ink.

2. The system of claim 1 wherein the print engine of the printer is a thermal print engine.

3. The system of claim 1 wherein the program instructions in the memory of the computer instruct the computer to provide a workplace window and a series of electrical circuit icons, wherein a user via the program instructions (a) selects an icon via the input device and (b) drags and positions the icon to a selected position in the workplace window to couple the selected icon with at least one other icon in the workplace window.

4. The system of claim 1 wherein the program instructions in the memory instruct the computer to receive a file previously generated under a computer-aided design application, and convert the file into print instructions that represent a desired electrical circuit.

5. A method of forming a printed circuit comprising:

providing a substrate;

defining a first pattern of conductive material for the substrate;

producing a digital representation of the defined first pattern;

producing a first set of electrical signals corresponding to the defined first pattern; and

activating a print engine with the set of electrical signals to print a conductive ink according to the defined first pattern.

6. The method of claim 5, further comprising:

defining a second pattern of dielectric material for the substrate;

producing a second set of electrical signals corresponding to the defined second pattern;

activating the print engine with the second set of electrical signals to produce the second pattern of dielectric material on the substrate, wherein at least a portion of second pattern of dielectric material is printed over a portion of the first pattern;

defining a third pattern of conductive material for the substrate;

producing a third set of electrical signals corresponding to the defined third pattern;

activating the print engine with the third set of electrical signals to produce the third pattern of conductive material on the substrate, wherein at least a portion of the third pattern of conductive material is printed over the portion of the second pattern.

7. The method of claim 5, further comprising:

defining a second pattern of dielectric material for the substrate;

producing a second set of electrical signals corresponding to the defined second pattern; and

activating the print engine with the second set of electrical signals to produce the second pattern of dielectric material on the substrate.

8. The method of claim 5 wherein activating a print engine includes activating a first print head to print the conductive ink, and wherein the method further comprises:

defining a second pattern of dielectric material for the substrate;

producing a second set of electrical signals corresponding to the defined second pattern; and

activating a second print head in the print engine with the second set of electrical signals to produce the second pattern of dielectric material on the substrate.

9. A method of printing on a print media comprising:

defining a pattern of conductors on a print media; and

printing a conductive trace on the print media in the defined pattern by applying a conductive ink with a print head.

10. The method of claim 9 wherein defining a pattern of conductors includes defining a plurality of traces having first ends positioned about a central region and a plurality of free ends for coupling to external circuitry, and wherein the central region is sized to receive an integrated circuit chip for coupling to the first ends of the traces.

11. The method of claim 9, further comprising providing a print media having an integrated circuit secured thereto, and wherein defining a pattern of conductors includes defining a plurality of traces having first ends coupled to terminals of the integrated circuit.

12. The method of claim 9 wherein printing a conductive trace includes thermally activating a ribbon having a conductive ink to transfer the conductive ink to the print media.

13. The method of claim 9, further comprising bonding an electronic device to the print media, the electronic device being electrically coupled to at least a portion of the conductive trace.

14. The method of claim 9 wherein defining a pattern of conductors includes defining a plurality of traces having first ends positioned about a central region at a plurality of holes formed through the print media, and a plurality of free ends for coupling to external circuitry and holes are sized to receive an integrated circuit chip and leads, respectively, for coupling to the first ends of the traces.

15. The method of claim 9 wherein defining a pattern of conductors includes defining a plurality of traces having first ends positioned to be electrically coupled to an integrated circuit chip, and wherein the method further includes:

automatically positioning the integrated circuit chip proximate to the first ends of the traces, and soldering the integrated circuit chip to the first ends of the traces.

16. The method of claim 9, further comprising adhering an integrated circuit to the print media and electrically coupling the integrated circuit to a portion of the printed conductive trace.

17. The method of claim 9, further comprising adhering, using an adhesive, an integrated circuit to the print media and electrically coupling the integrated circuit to a portion of the printed conductive trace, and

curing the adhesive following the step of adhering.

18. The method of claim 9 wherein the print media includes preformed conductive pads formed thereon, and wherein printing a conductive trace includes printing the conductive trace having a first end printed and electrically coupled to at least one of the conductive pads.

19. The method of claim 9, further comprising electrically coupling an integrated circuit to a portion of the printed conductive trace and securing a protective overlay over the integrated circuit and at least a portion of the print media.

20. The method of claim 9 wherein printing a conductive trace includes printing an antenna on the print media with the conductive ink, and electrically coupling thereto an electronic receiver secured to the print media.

21. The method of claim 9, further comprising:

defining another pattern of conductors;

printing another conductive trace on another print media in the another defined pattern; and

securing the print media and the another print media together to form a stacked assembly, wherein the conductive trace and the another conductive trace are electrically coupled.

22. An article of manufacture for a printer comprising:

print media of a flexible, planar and electrically insulative material and having a first side for receiving conductive traces printed thereon, wherein the print media has secured thereto a plurality of spaced apart conductive members, and wherein at least one hole in the print media expose a portion of at least some of the conductive members.

23. The article of manufacture of claim 22 wherein the pairs of holes are positioned on the first side of the print media, and wherein the conductive members are elongated and at least partially embedded in the print media.

24. The article of manufacture of claim 22 wherein the print media includes first and second layers of insulative material having sandwiched therebetween the plurality of spaced apart conductive members, and wherein the first and second layers have holes that expose opposite portions of at least some of the conductive members.

25. The article of manufacture of claim 22 wherein the spaced apart conductive members are patches of conductive foil secured to at least one side of the planar and electrically insulative material, wherein the patches of conductive foil are positioned about at least some of the holes.

26. The article of manufacture of claim 22 wherein one of the pairs of holes is positioned on the first side of the print media, while the other of the pairs of holes is positioned on an opposite side of the print media.

27. The article of manufacture of claim 22 wherein at least one of the holes in each of the pair of holes are positioned on the first side of the print media in staggered rows.

28. An article of manufacture for a printer comprising:

print media of a planar, flexible and electrically insulative material, wherein the print media has a plurality of areas of a conductive material formed on the print media, and wherein the first side of the print media is for receiving conductive traces printed thereon, including conductive traces printed and electrically coupled to at least some of the patches of conductive material.

29. The article of manufacture of claim 28 wherein at least some of the conductive areas are positioned about a central region, and wherein the central region is sized to receive an integrated circuit chip for electrical coupling leads of the integrated circuit chip to the conductive areas positioned about the central region.

30. The article of manufacture of claim 28 wherein at least one of the areas of conductive material forms a first plate of a capacitor, and wherein a second plate of the capacitor is subsequently printed.

31. The article of manufacture of claim 28 wherein at least some of the conductive patches are preformed EISA traces, wherein the EISA traces are abrasion resistant.

32. A method of printing a security card comprising:

providing a card media;

defining a pattern of conductors, wherein the pattern of conductors selectively define electrical circuits when coupled to external circuitry; and

printing conductive patterns on the card media in the defined pattern by applying a conductive ink with a print engine.

33. The method of claim 32, further comprising covering the printed conductive patterns with a dielectric material, wherein the dielectric material permits capacitive coupling of external circuitry to at least a portion of the printed conductive patterns.

34. The method of claim 32, further comprising printing a machine readable symbol on the card media.

35. The method of claim 32, further comprising printing an image of a user on the card media.

36. A printer comprising:

a print engine operative to print a conductive material in a pattern defined by a first electrical signal; and

a print controller coupled to the print engine, wherein the print controller is operative to receive data representing an electrical circuit to be printed and to provide the first electrical signal responsive to the received data.

37. The printer of claim 36 wherein the print engine includes a first print head for printing the conductive material, and includes a second print head operative to print a dielectric material in response to a second electrical signal, wherein the print controller is coupled to the second print head and is operative to produce the second electrical signal in response to the received data.

38. The printer of claim 36 wherein the print engine includes a print head for printing the conductive material and for printing an insulative material in response to a second electrical signal, wherein the print controller is coupled to the print head and is operative to produce the second electrical signal in response to the received data.

39. The printer of claim 36, further comprising print media having a plurality of holes formed therethrough, and wherein the print engine is operative to print the conductive material on both sides of the print media, where printed conductive material printed on opposite sides of the print media about one of the holes forms an electrically connected via therebetween.

40. The printer of claim 36, further comprising a measuring circuit coupled to a pair of probes, wherein the probes contact print media that exits downstream from the print engine and electrically couples to conductive material printed by the print engine, and wherein the measuring circuit measures an electrical property of the printed conductive material via the probes.

41. The printer of claim 36 wherein the print engine includes a thermal print engine.

42. The printer of claim 36 wherein the print engine includes an impact print engine.

43. The printer of claim 36 wherein the print engine includes a xerographic print engine.

44. The printer of claim 36, further comprising first and second ribbons positioned relative to the print engine, wherein the first and second ribbons contain the conductive material and a dielectric material, respectively, for printing by the print engine.

45. The printer of claim 36, further comprising a ribbon positioned relative to the print engine, wherein the ribbon includes first and second sections having the conductive material and a dielectric material, respectively, for printing by the print engine.

46. The printer of claim 36 wherein the print engine includes an ink jet print engine.

47. A ribbon for a printer comprising:

a carrier layer;

an ink layer having an electrically conductive material; and

a release layer formed between the carrier layer and the ink layer.

48. The ribbon of claim 47, further comprising another ink layer having a predetermined electrical characteristic, wherein the ink layer and another ink layer are positioned as parallel longitudinally extending regions on the carrier layer.

49. The ribbon of claim 47, further comprising another ink layer having a predetermined electrical characteristic, wherein the ink layer and another ink layer are positioned as a plurality of alternating and transversely extending regions.

50. The ribbon of claim 47, further comprising another ink layer, and wherein the another ink layer has dielectric electric properties.

51. The ribbon of claim 47, further comprising another ink layer, and wherein the another ink layer has magnetic properties.

52. The ribbon of claim 47 wherein the ink layer is formed as a plurality of conductive particles held in a matrix of binding material.

53. The ribbon of claim 47, further comprising an adhesive layer formed over the ink layer.

54. The ribbon of claim 47, further comprising first and second additional ink layers, the first and second additional ink layers having differing electrical resistive values, wherein the ink layer, and the first and second additional ink layers are positioned as discrete regions on the carrier layer.

55. The ribbon of claim 47, further comprising first and second additional ink layers, the first and second additional ink layers having differing electrical capacitance values, wherein the ink layer, and the first and second additional ink layers are positioned as discrete regions on the carrier layer.

56. A printer, comprising:

a first print head;

a first ribbon aligned to the first print head, the first ribbon containing a conductive first ink;

a second print head;

a second ribbon aligned to the second print head, the second ribbon containing a second ink; and

a driving mechanism configured to sequentially transport a print media past the first and second print heads.

57. The printer of claim 56, further including a third print head wherein the driving mechanism is configured to transport the print media past the third print head.

58. The printer of claim 56 wherein the first and second ribbons are separate ribbons.

59. The printer of claim 56 wherein the first and second ribbons are portions of a common ribbon.

60. The printer of claim 56 wherein the second ink is a dielectric ink.

61. The printer of claim 56 wherein the second ink is of an n-type or p-type doped material.

62. The printer of claim 56, further comprising:

a memory device containing image data;

a first electronic print head driver coupled to the first print head;

a second print head driver coupled to the second print head; and

an electronic controller coupled to the memory device and the first and second print head drivers, the controller being configured to retrieve the image data and to activate the first and second print heads in response to the image data.

63. A method of producing a remotely readable device comprising:

printing a first set of conductive traces on a print media with a printer by transferring conductive ink to the print media; and

printing a dielectric layer on the print media with the printer by transferring a dielectric ink to the print media.

64. The method of claim 63, further comprising:

printing a second set of conductive traces on the print media by transferring conductive ink from a ribbon to the print media.

65. The method of claim 63, further comprising:

printing a set of ferromagnetic traces on the print media by transferring a ferromagnetic ink to the print media.

66. The method of claim 63 wherein the step of transferring conductive ink includes moving the print media and a first ribbon having conductive ink relative to a first print head in the printer.

67. The method of claim 66, further comprising:

printing a second set of conductive traces on the print media by transferring conductive ink from a second ribbon to the print media, and wherein the

printing of a dielectric layer on the print media includes moving the print media and second ribbon relative to a second print head in the printer.

68. The method of claim 63 wherein the printing of a first set of conductive traces transfers conductive ink from a first ribbon to the print media, and wherein the printing of a dielectric layer includes transferring a dielectric ink from a second ribbon to the print media, and wherein the first and second ribbons are a common ribbon.

69. The method of claim 68, further comprising producing lateral movement of the common ribbon relative to the print media between the printing of the first set of conductive traces and the printing of the dielectric layer.

70. A method of creating circuit elements comprising:

providing a print media;

defining a first pattern for conductive material;

defining a second pattern for insulative or resistive material;

printing conductive material on the print media in the first defined pattern by applying a conductive ink with a print engine; and

printing insulative or resistive material on the print media in the second defined pattern by applying an insulative or resistive ink with the print engine.

71. The method of claim 70 wherein the printing of conductive material includes printing spaced apart first and second terminals of the conductive material on the print media, and wherein the printing of insulative or resistive material includes printing resistive material between, and electrically coupled to, the first and second terminals.

72. The method of claim 70 wherein the printing of conductive material includes printing a first area of the conductive material on the print media,

wherein the printing of insulative or resistive material includes printing insulative material over the first area, and wherein the method further comprises printing a second area of the conductive material over the printed insulative material.

73. The method of claim 70, further comprising:

printing first regions of one of an N-type or P-type doped material on the print media, and

printing second regions, relative to the first regions, of the other of the N-type or P-type doped material on the print media.

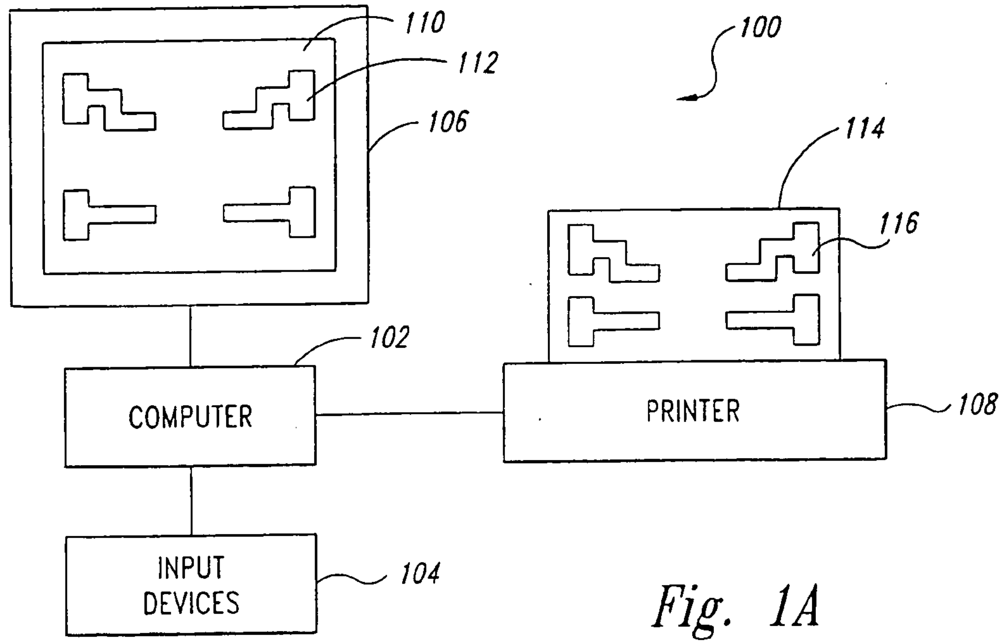
110
112
100
106
114
116
102
COMPUTER
PRINTER
108
INPUT
DEVICES
104

Fig. 1A

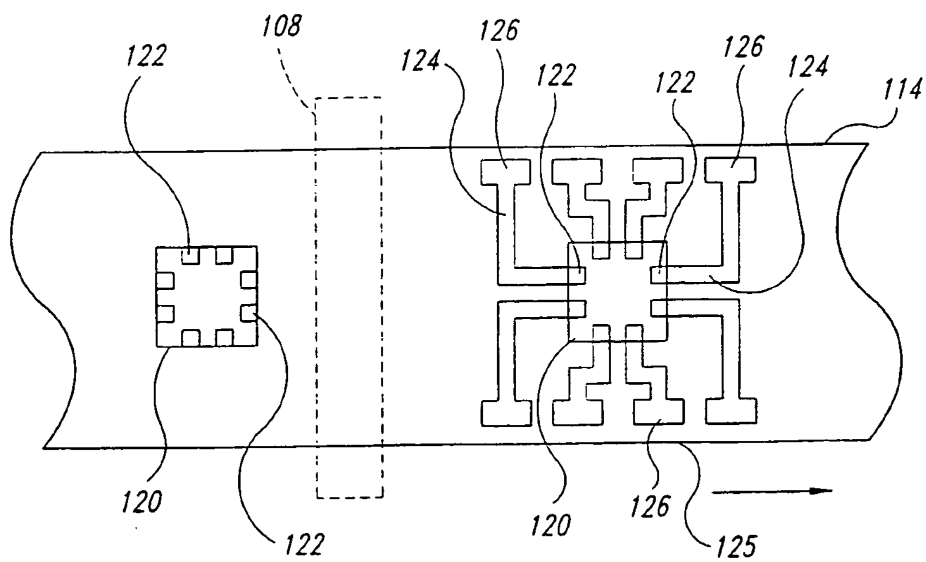
108
122
124
126
122
122
126
124
114
120
122
120
126
125

Fig. 2

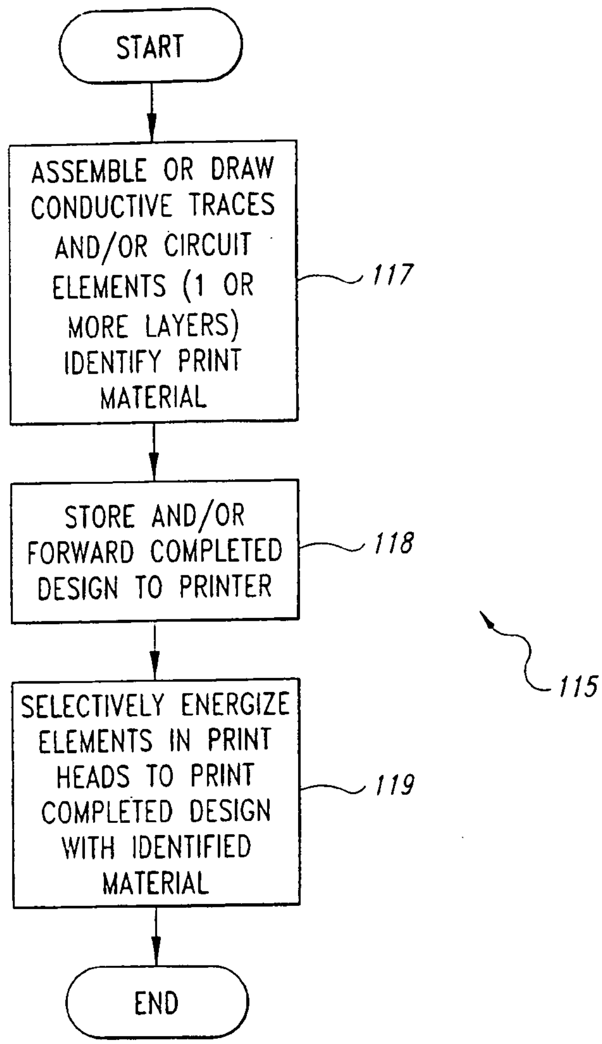
START
ASSEMBLE OR DRAW CONDUCTIVE TRACES AND/OR CIRCUIT ELEMENTS (1 OR MORE LAYERS) IDENTIFY PRINT MATERIAL
117
STORE AND/OR FORWARD COMPLETED DESIGN TO PRINTER
118
115
SELECTIVELY ENERGIZE ELEMENTS IN PRINT HEADS TO PRINT COMPLETED DESIGN WITH IDENTIFIED MATERIAL
119
END

Fig. 1B

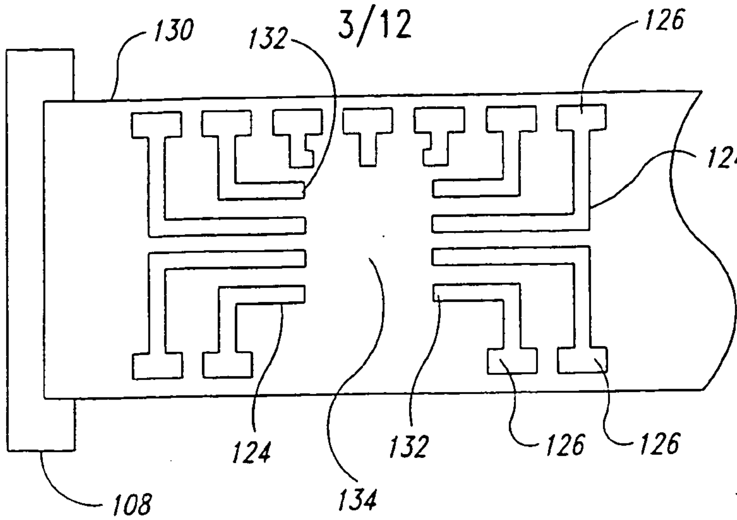

Fig. 3

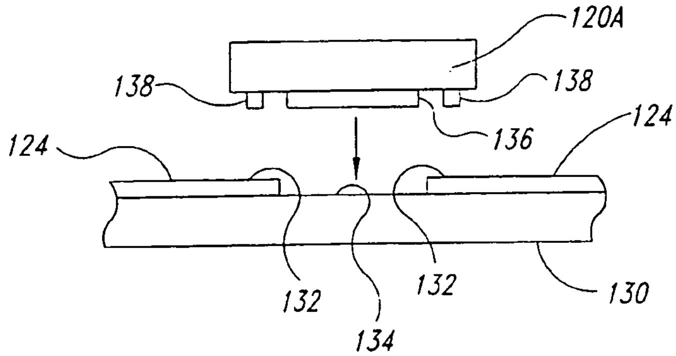

Fig. 4

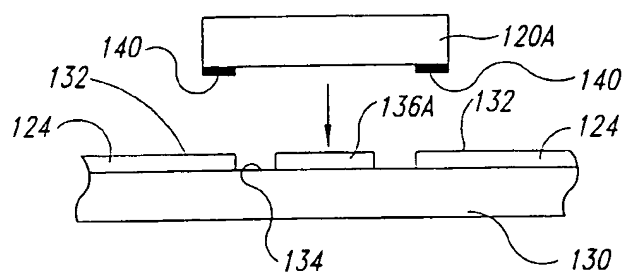

Fig. 5

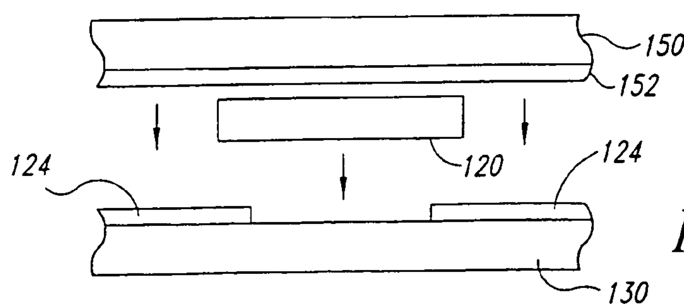

Fig. 6A

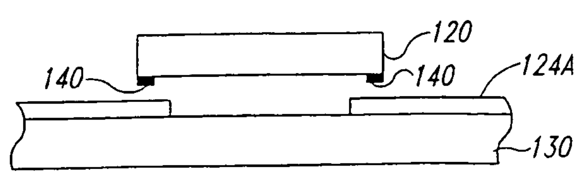

Fig. 6B

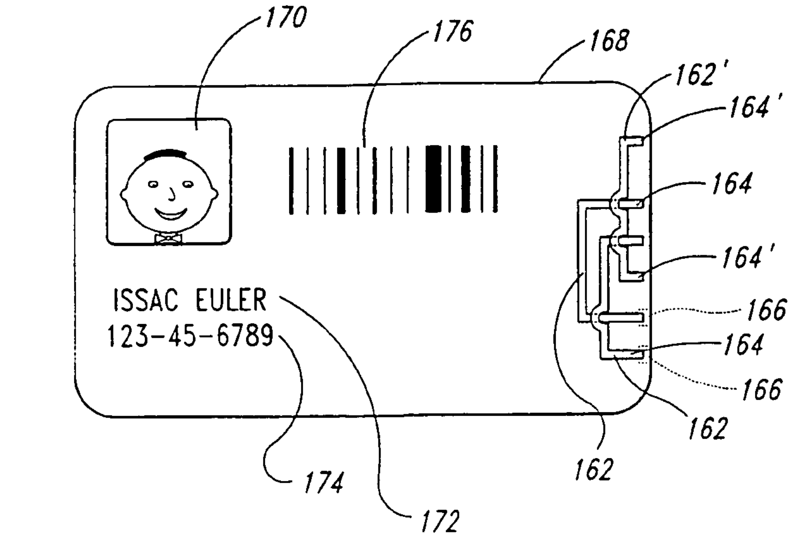

Fig. 7

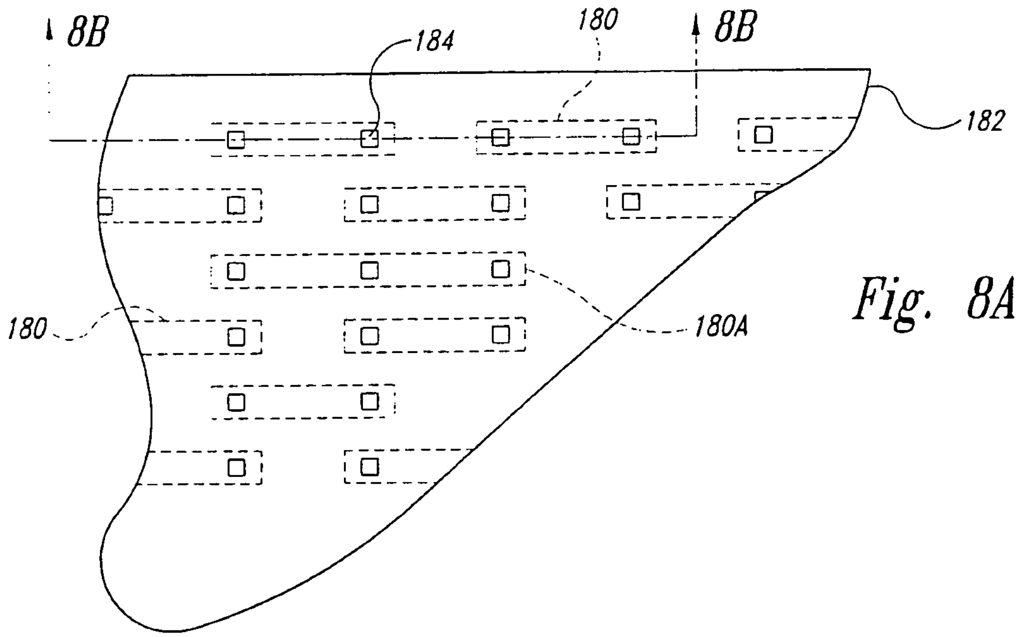

Fig. 8A

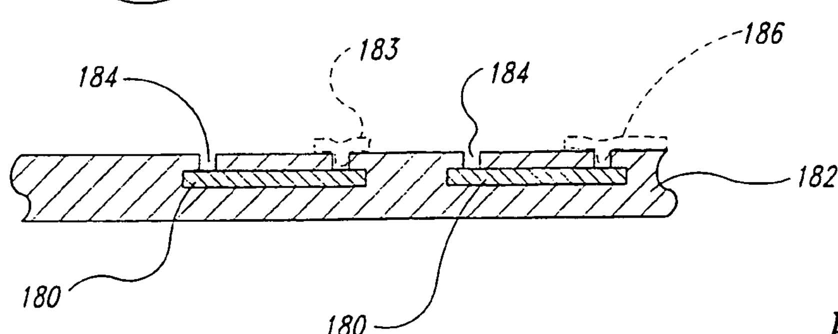

Fig. 8B

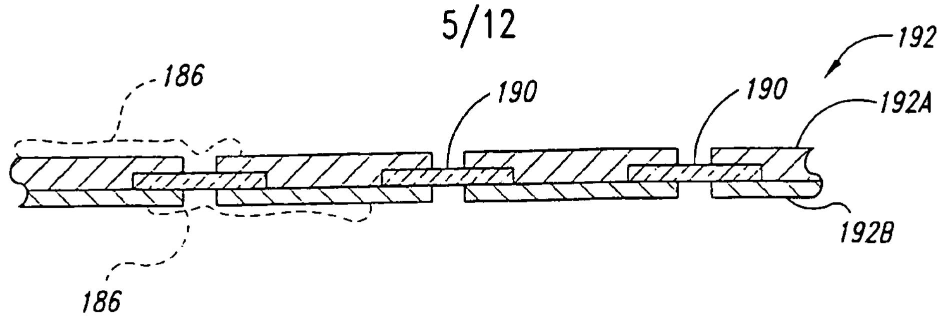

Fig. 9B

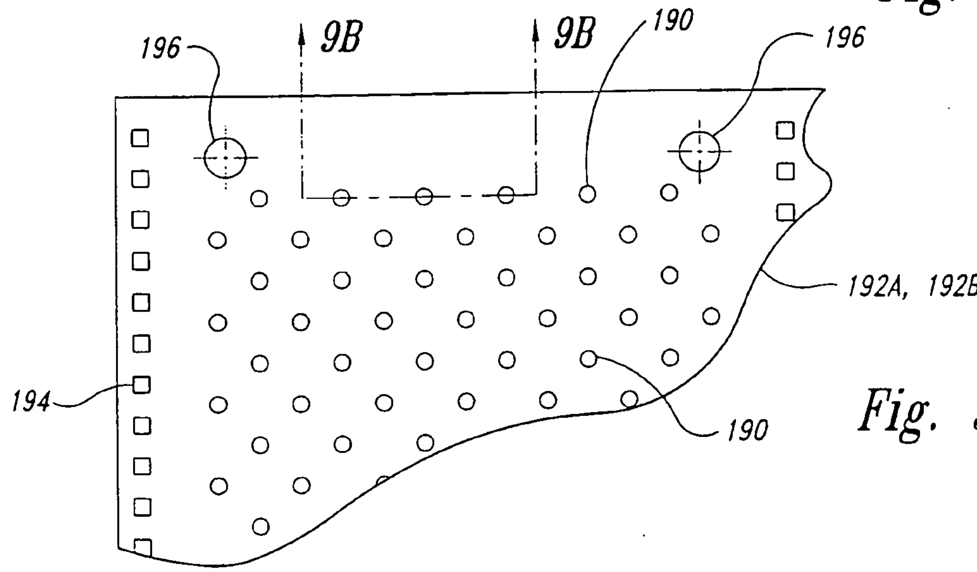

Fig. 9A

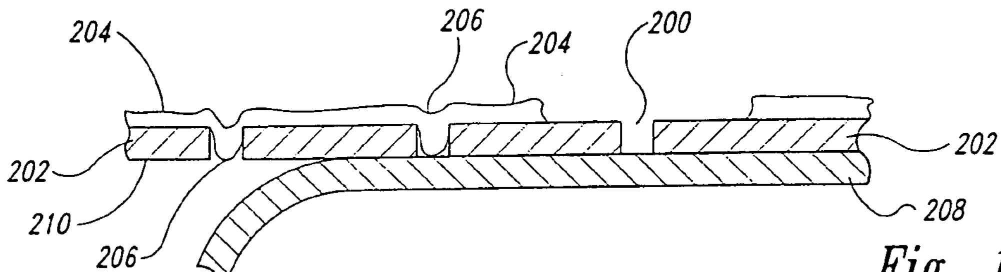

Fig. 10B

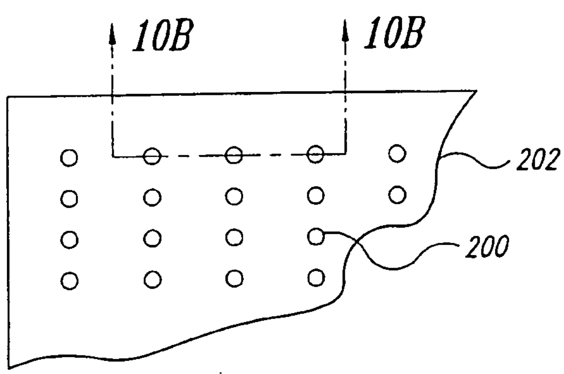

Fig. 10A

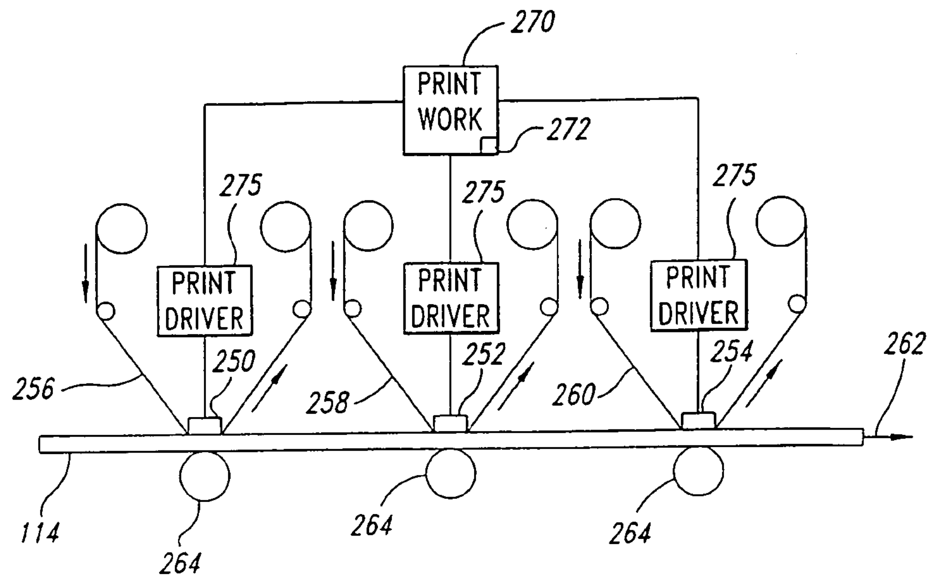

Fig. 11

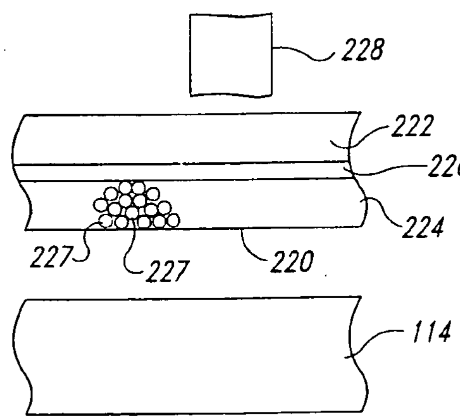

Fig. 12

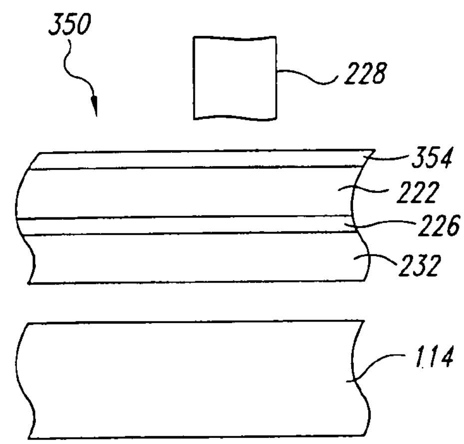

Fig. 13B

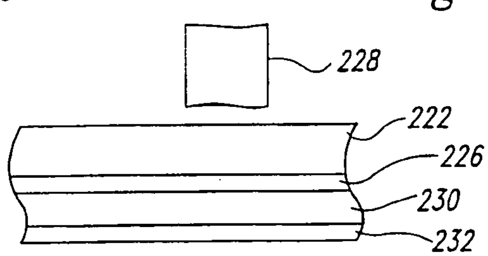

Fig. 13A

7/12

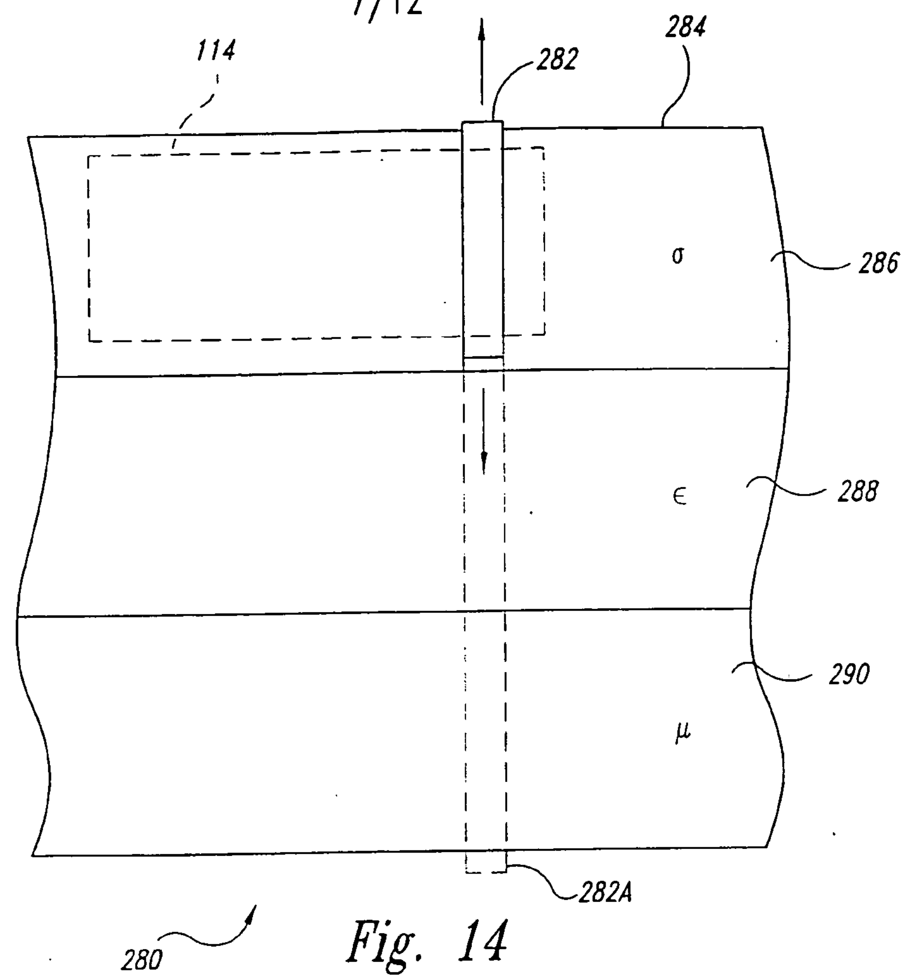

Fig. 14

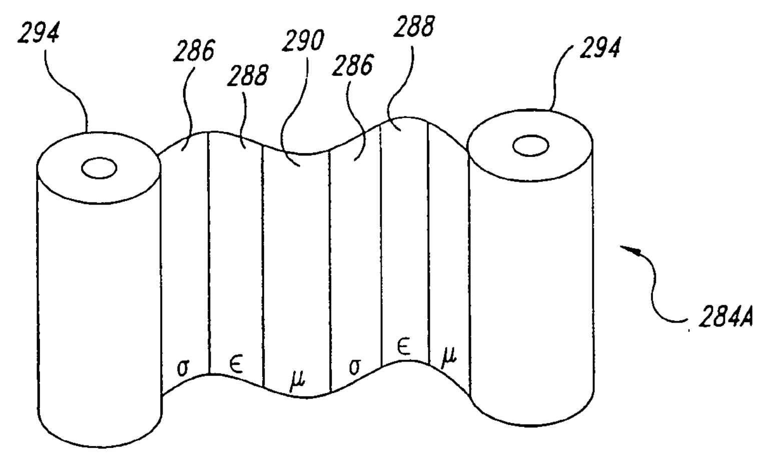

Fig. 15

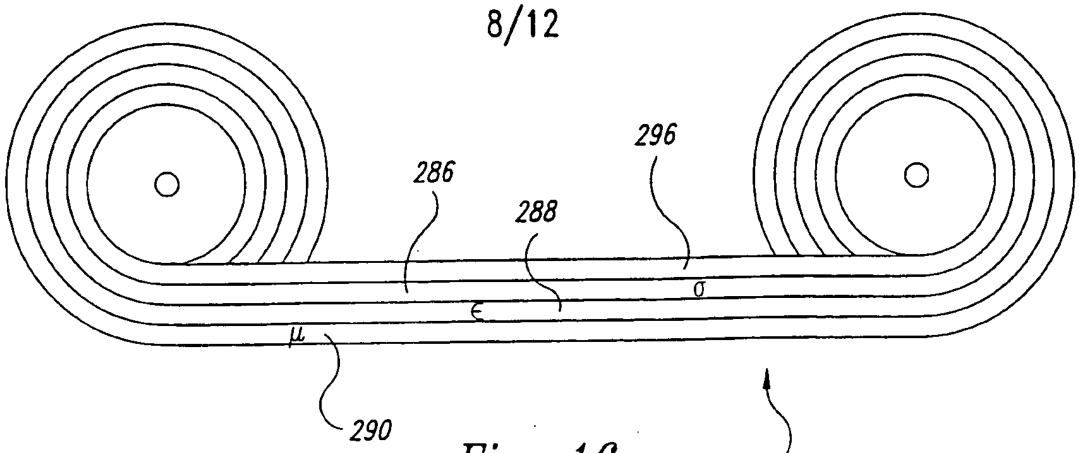

Fig. 16

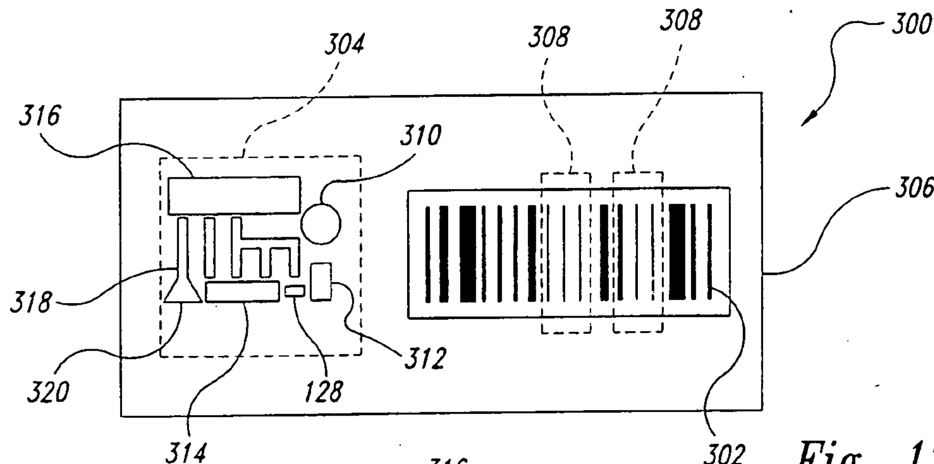

Fig. 17

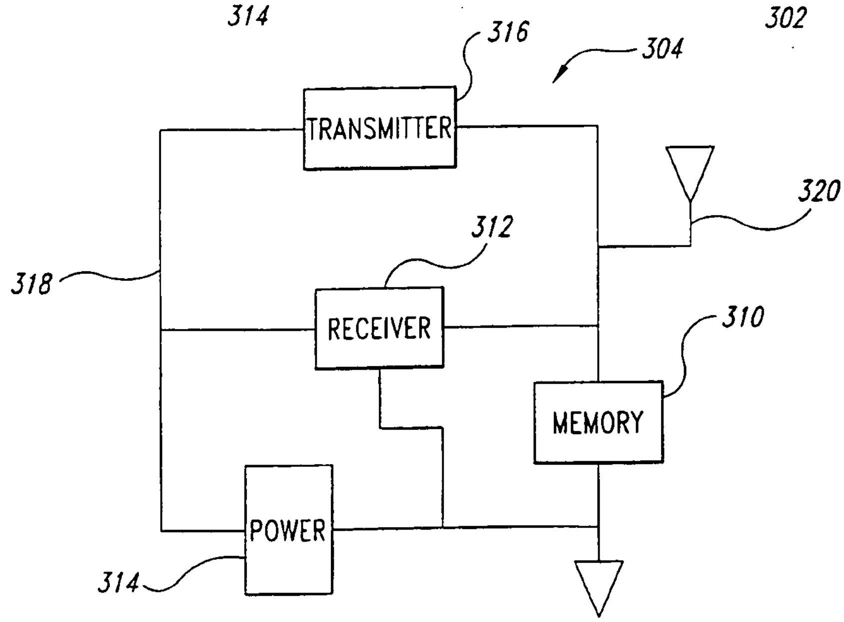

Fig. 18

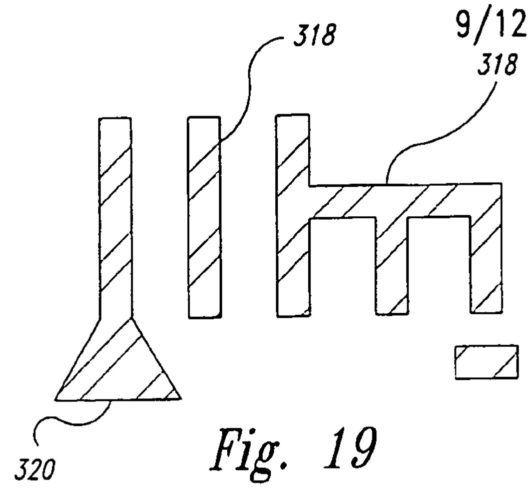

Fig. 19

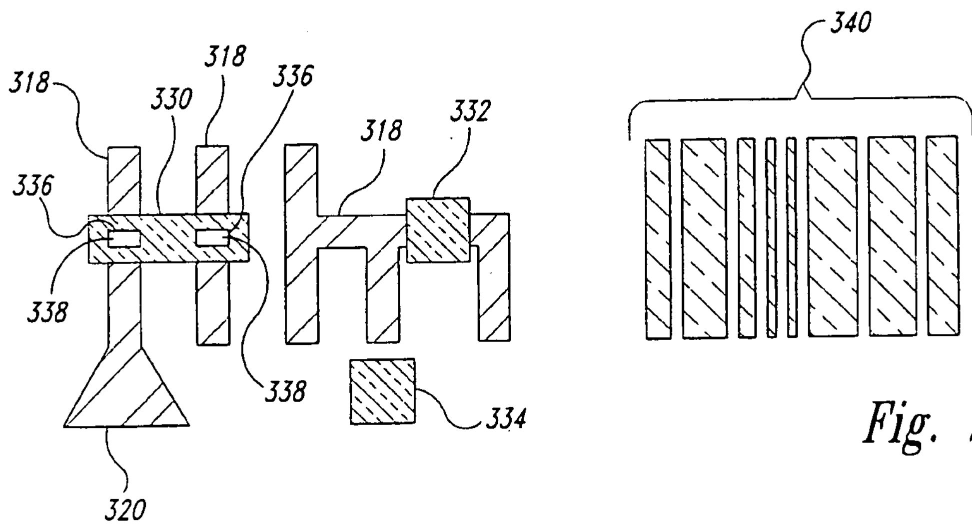

Fig. 20

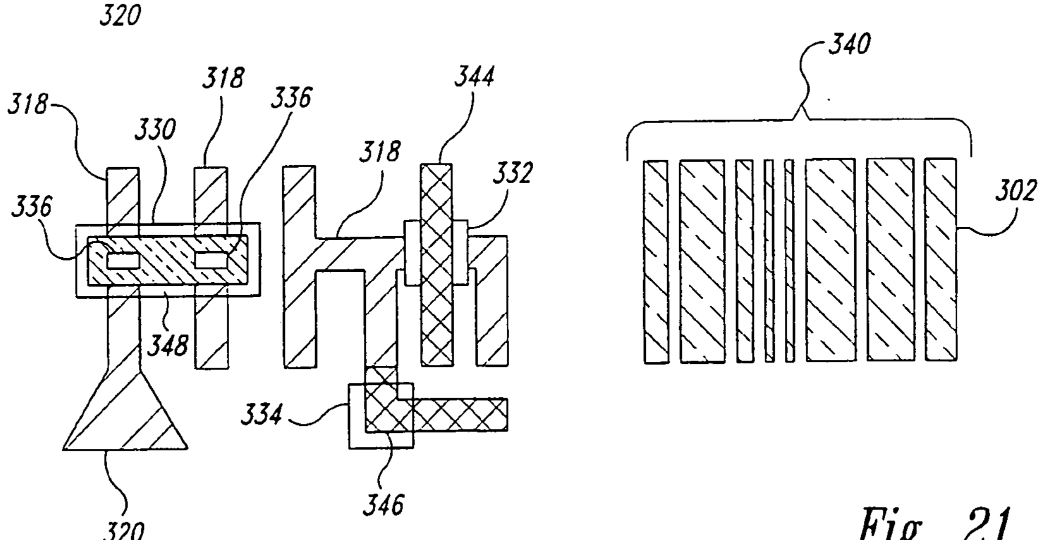

Fig. 21

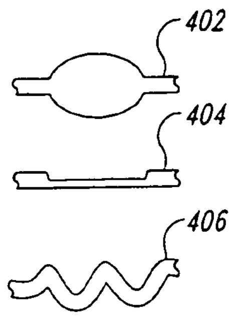

Fig. 22

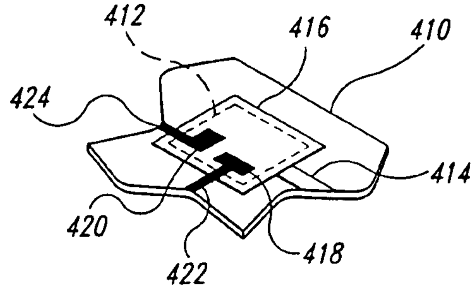

Fig. 23

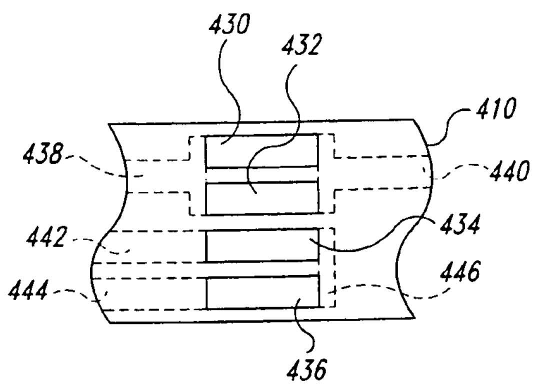

Fig. 24

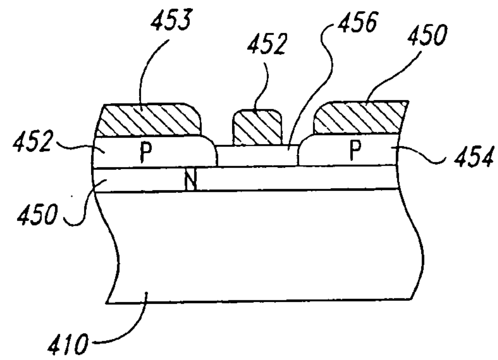

Fig. 25

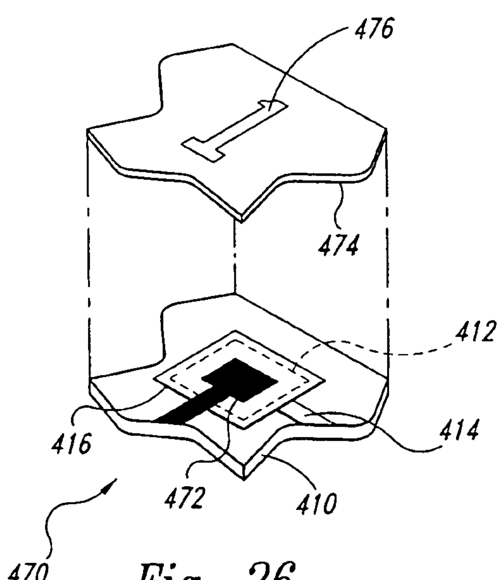

Fig. 26

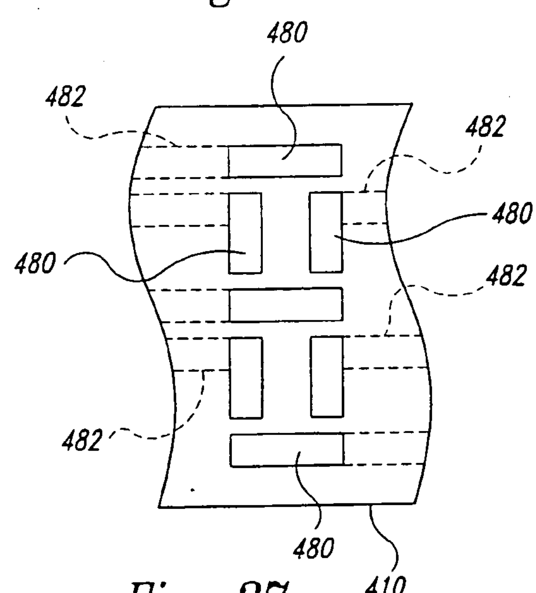

Fig. 27

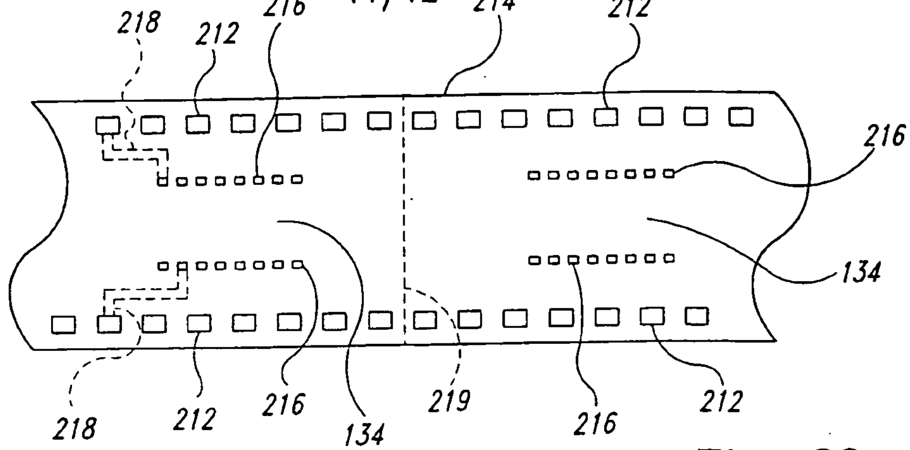

Fig. 28

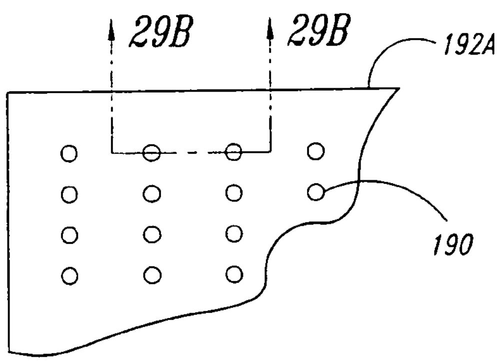

Fig. 29A

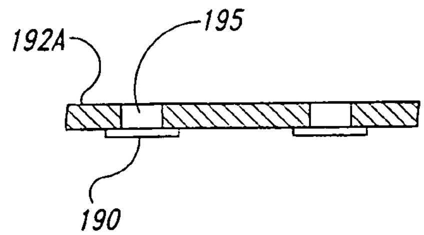

Fig. 29B

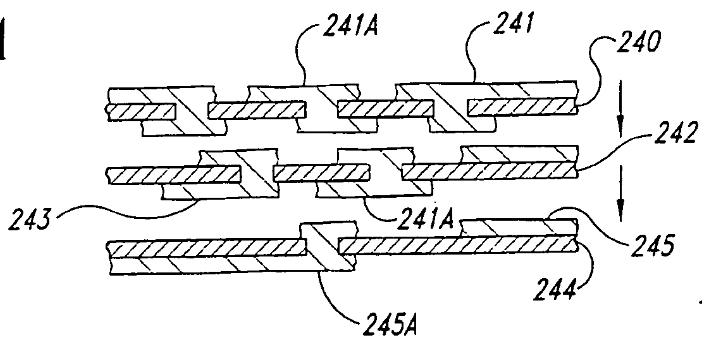

Fig. 30

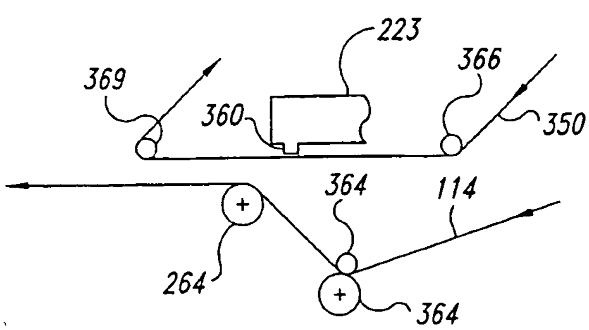

Fig. 31

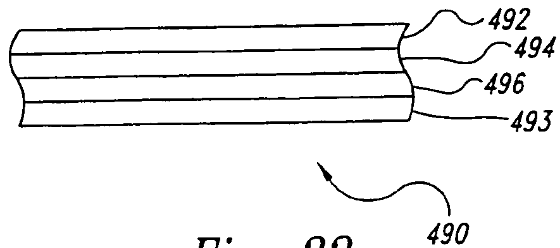

Fig. 32

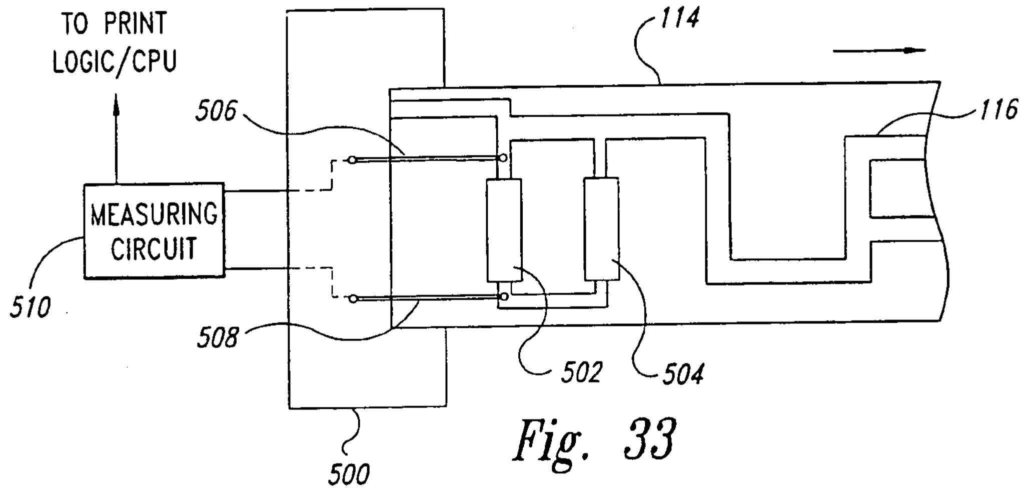

Fig. 33

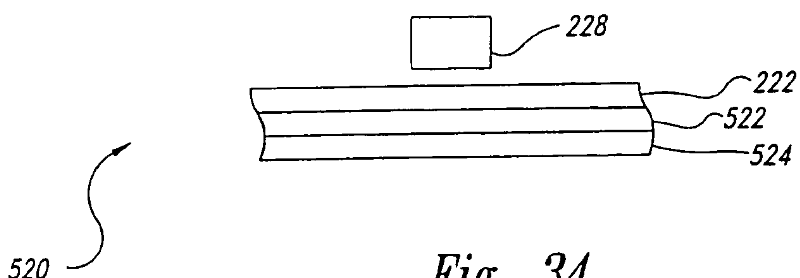

Fig. 34

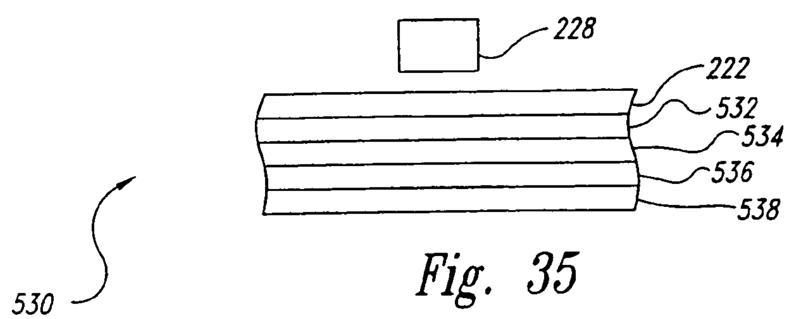

Fig. 35